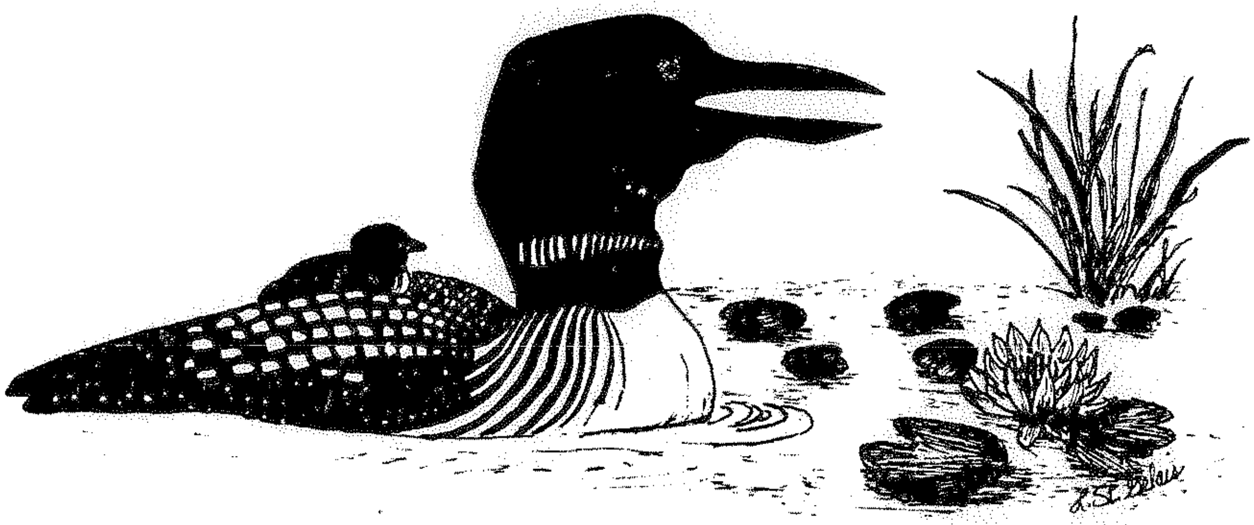
MOULTONBOROUGH BAY
Water Quality Monitoring: 2005
Summary and Recommendations
NH LAKES LAY MONITORING PROGRAM



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UNIVERSITY of NEW HAMPSHIRE
COOPERATIVE EXTENSION

To obtain additional information on the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at 603-862-3848 or Assistant Coordinator (Bob Craycraft) at 603-862-3696.

PREFACE

This report contains the findings of a water quality survey of Lake Winnipesaukee conducted in the summer of 2005 by the University of New Hampshire **Center For Freshwater Biology (CFB)** in conjunction with the Lake Winnipesaukee Association and interested lakeshore residents within the towns of Moultonborough and Tuftonboro.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of the 2005 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

ACKNOWLEDGMENTS

2005 was the twenty-fourth year Lake Winnipesaukee was monitored in conjunction with the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while the Lake Winnipesaukee Association provided additional logistical support that included the transport of water samples to the University of New Hampshire laboratory for analysis. The **Center for Freshwater Biology (CFB)** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join the Lake Winnipesaukee water quality monitoring effort in 2006 and expand upon the growing database. Funding for the water quality monitoring program was provided by the Lake Winnipesauke Association, the Town of Tuftonboro and the Langdon Cove Association.

Table 1: Winnipesauke, Moultonborough Bay Volunteer Monitors (2005)

Monitor Name	Lake Monitored
Larry DeGeorge	5 Melvin Bay
Gerry DeGeorge	5 Melvin Bay
Headley S. White Jr.	20 Mile Bay
Terri White	20 Mile Bay
Francis W. Laase	19 Mile Bay (A & B)
Ellen Laase	19 Mile Bay (A & B)
Mike Robinette	49 Greens Boathouse
Muriel Robinette	49 Greens Boathouse
Morgan Robinette	49 Greens Boathouse
John Landrine	Greens Basin
Marcia Landrine	Greens Basin
Thomas Given	3 Langdon Cove
Wesley Wallace	3 Langdon Cove

The **Center for Freshwater Biology** is a not-for-profit research program coordinated by Jeffrey Schloss and Robert Craycraft. Members of the **CFB** summer field team included Ashlee Cieslak, Laura Morcom and Michelle Williams while Thais Fournier, Adam Karr, Kellie Norris, Cassandra Payne and Julie Shelly provided additional assistance in the fall compiling and organizing the water quality data.

The **CFB** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office and storage space while the College of Life Sciences and Agriculture provided laboratory facilities and additional storage space. The **CFB** would like to thank the **Caswell Family Foundation** for their generosity in providing long-term support for undergraduate assistantships. A gift from the **Samuel P. Pardoe Foundation** allowed for an update of our volunteer temperature profiling equipment, as well as, financial support to develop a data server for our **LLMP** web site while the **United States Geological Survey**, through the **University of New Hampshire Water Resources Research Center**, provided some resources for staff support. Additional support for administering the **NH LLMP** comes from the **United States Department of Agriculture Cooperative State Research, Education and Exten-**

sion Service through support from the New England Regional Water Quality Program (http://www.usawaterquality.org/newengland/).

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Dublin Garden Club, Eaton Conservation Commission, Governor's Island Club Inc., Green Mountain Conservation Group, Meredith Bay Rotary Club, The New Hampshire Audubon Society, North River Lake Water Quality Audit Committee, Walker's Pond Conservation Society, the associations of Baboosic Lake, Bow Lake Camp Owners, Chocorua Lake, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Silver Lake (Madison), Squam Lakes, Sunset Lake, Swains Lake, Lake Wentworth, Winnisquam Drive, and the towns of Alton, Amherst, Enfield, Madison, Meredith, Merrimack, Milton, Strafford, Whitefield and Wolfeboro.

Winnipesaukee – Langdon Cove 2005 Non-Technical Summary

Water quality data were collected by the Lake Winnipesaukee—Langdon Cove volunteer monitors between May 20 and September 30, 2005. Generally speaking, the 2005 Langdon Cove water quality remained excellent as summarized in Table 2; the 2005 Langdon Cove water clarity was high while the microscopic plant abundance (greenness) was generally low and remained below nuisance levels.

Table 2: 2005 Langdon Cove Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Winnipesaukee – Langdon Cove Average (range)	Langdon Cove Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	5.3 meters (range: 4.2 – 6.6)	Oligotrophic
Chlorophyll *a* (ppb)	< 3.0	3.0 - 7.0	> 7.0	2.5 ppb (range: 1.9 – 4.3)	Oligotrophic

Langdon Cove was characterized by less clear water in 2005, relative to the 2004 median water transparency while the amount of microscopic plant growth (visually detectible as a greenness to the water) was similar to the 2004 level.

Water quality data were compared among the Lake Winnipssaukee sampling locations located in the towns of Moultonborough and Tuftonboro (Figures 39 and 40); the 2005 Langdon Cove Secchi Disk transparency measurements were higher (i.e. clearer water) than the measurements documented at the most northerly sampling location, Greens Basin, but were significantly shallower than the clarities documented on the easterly side of Long Island, Site 49 Greens Boathouse (Figure 39) The 2005 Langdon Cove chlorophyll *a* data were lower (i.e. less algal greenness) than the concentrations documented in Greens Basin but were significantly higher than the concentrations documented in 20 Mile Bay, 19 Mile Bay and near Greens Boathouse (Figure 40). The chlorophyll *a* data exhibit a general trend of decreasing chlorophyll *a* concentrations (i.e. decreasing algal greenness) from the northerly sampling location, Greens Basin, to the most southerly sampling locations in 19 Mile Bay (Figure 40).

The following section discusses the 2005 and historical Langdon Cove water quality data. *Refer to Appendix A for a complete listing of the 2005 Langdon Cove water quality data and refer to Appendix B for a primer on interpreting the box and whisker plots that are included in the 2005 annual report.*

1) **Water Clarity (measured as Secchi Disk transparency)** – The Langdon Cove Secchi Disk transparency values were high and remained above 13.2 feet (4 meters) that is considered the boundary between an unproductive "pris-

tine" and more nutrient enriched "transitional" New Hampshire lake (Figures 13 and 14). The Langdon Cove Secchi Disk transparency measurements were slightly shallower, during the months of May and June, relative to the water transparency measurements that were documented later in the year.

The 2005 Langdon Cove Secchi Disk transparency measurements increased (i.e clearer water), relative to the 2004 levels, and remained well within the range of seasonal average values documented since volunteer water quality monitoring was initiated on Langdon Cove in 1982 (Figure 27). No new water transparency minimum or maximum values were documented in 2005.

2) **Microscopic plant abundance "greenness" (measured as chlorophyll *a*)** – The 2005 Langdon Cove chlorophyll *a* measurements generally remained below the concentration of 3 parts per billion (ppb) that is considered the boundary between a nutrient poor and more nutrient enriched "greener" lake (Figure 13 and Table 2). The highest chlorophyll *a* concentration was documented on August 10, during which the concentration reached 4.0 ppb. However, all of the 2005 chlorophyll *a* concentrations remained below nuisance levels.

The 2005 Langdon Cove chlorophyll *a* concentrations were similar to the 2004 concentrations and no new minimum or maximum chlorophyll *a* concentrations were documented during the 2005 sampling season (Figure 28).

3) **Background (dissolved) water color: often perceived as a "tea" color in more highly stained lakes** – The 2005 Langdon Cove dissolved color concentration averaged 23.9 chloroplatinate units (cpu) and fell within the classification of a lightly "tea" colored lake (Table 3). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality.

Table 3. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range (mg/L)	Classification
0 - 10	Clear
10 - 20	Slightly colored
20 - 40	Light tea color
40 - 80	Tea colored
> 80	Highly tea colored

4) **Resistance against acid precipitation (measured as total alkalinity)** – The 2005 Langdon Cove alkalinity measured 7.0 milligrams per liter (mg/l) which is considered typical of a lake with a moderate vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 4). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) which increases the buffering capacity in our surface waters. Thus, lakes in the vicinity

(e.g. Squam Lake and Mirror Lake) have naturally low alkalinities. While the Langdon Cove alkalinity was low in 2005, it remained sufficient to buffer against acid precipitation that can be stressful to many freshwater organisms.

Lake acidity (measured as pH) – the most recent pH data, collected by the **Center for Freshwater Biology** in Melvin Bay on August 23, 2005, ranged from 7.2 to 7.3 units in the surface waters and remained well within the tolerable range for most aquatic organisms.

Table 4. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range	Classification
< 0	Acidified
0 -2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

5) Based on the current and historical water quality data, Langdon Cove would be considered a moderately nutrient enriched "transitional" portion of Lake Winnipesaukee that has been characterized by relatively high water transparencies and moderate levels of microscopic plant "algal" abundance over the past twenty-three years of volunteer monitoring. A first step towards preserving the high water quality in Langdon Cove is to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake since the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained**, and have it pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and can result in early failure, that costs thousands of dollars to repair or replace.

It is also important to make sure the watershed residents are well educated on water quality related issues. Numerous publications are available through University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services as well as several other local, state and federal agencies. Refer to the section "Understanding Lake Aging" for further information.

Winnipesaukee - Long Island 2005 Non-Technical Summary

Water quality sampling was conducted on the eastern side of Long Island, near Greens Boathouse, between May 1 and September 24, 2005. Generally speaking, the 2005 Long Island water quality remained excellent as summarized in Table 5; the water clarity was high and averaged 24.4 feet (7.4 meters) while the amount of microscopic plant "algal" growth (measured as chlorophyll *a*) was low and remained below nuisance levels. *Refer to Appendix A for a complete listing of the 2005 Long Island water quality data.*

Table 5: 2005 Long Island Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Winnipesaukee – Long Island Average (range)	Long Island Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	7.4 meters (range: 6.5 – 9.0 meters)	Oligotrophic
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	1.7 ppb (range: 0.9 – 2.6 ppb)	Oligotrophic

The sampling locations located in Lake Winnipesaukee (Towns of Tuftonboro and Moultonborough) were characterized by similar or less clear waters in 2005, relative to the levels documented during the 2004 sampling season (Figures 27, 29, 31, 33, 35, and 37). The 2005 median Greens Boathouse water transparency declined for the second consecutive year (Figure 29). A review of the 2005 chlorophyll *a* concentrations indicated that the median algal concentrations were near or below the 2005 concentrations at the Lake Winnipesaukee Sampling locations (Figures 28, 30, 32, 34, 36 and 38). The median 2005 Greens Boathouse chlorophyll *a* concentration was similar to the 2003 and 2004 median values (Figure 30).

There is no clear relationship between the water transparency measurements and the chlorophyll *a* concentrations (i.e. Secchi Disk decreases did not coincide with chlorophyll *a* increases) that suggest other factors, such as an increase in the amount of suspended sediments or an increase in mid-lake algal populations, had an impact on the water transparency decrease at the Greens Boathouse sampling location. The Greens Boathouse sampling station tends to be more susceptible to water quality problems than many regions of Lake Winnipesaukee. The reduced flushing along the eastern side of Long Island makes this region of the lake particularly vulnerable to localized pollutant inputs that can in-turn stimulate localized algal blooms and result in a concurrent decrease in water transparency. Future educational efforts should target local landowners on measures that can help reduce the phosphorus (nutrient) and sediment load into Lake Winnipesaukee.

Water quality data collected in the vicinity of Alton Bay, Center Harbor, Long Island, Meredith Bay and Moultonborough Bay were compared to discern regional water quality variations within Lake Winnipesaukee (Figures 41 & 42). The 2005 Long Island water transparency of 24.4 feet (7.4 meters) was near/above average when compared to other regional locations while the median microscopic plant (algal) concentration of 1.7 micrograms per liter (*u*g/l) documented at Site 49 Greens Boathouse was the highest concentration documented in Lake Winnipesaukee (Figures 41 & 42).

The 2005 water quality data, collected near Greens Boathouse, continued to indicate high water quality on the eastern side of Long Island. However, as indicated previously, the isolated nature of the Greens Boathouse sampling site (i.e. limited flushing) suggest that this location is more susceptible to water quality problems than many other locations around Lake Winnipesaukee. A first step towards preserving the high water quality characteristic of Lake Winnipesaukee-Long Island is to take action at the local level and do your part to reduce the amount of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake as the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained** and have it pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and result in early failure, costing thousands of dollars to repair or replace.

It is also important to make sure the watershed residents are well-educated on water quality related issues. Numerous publications are available through University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services as well as several other local, state and federal agencies. *Refer to the section "Understanding Lake Aging" for a list of publications pertinent to watershed protection.* It is imperative that future activities within the Lake Winnipesaukee-Long Island watershed are carefully thought out before implementation if water quality degradation is to be minimized.

Winnipesaukee (Towns of Moultonborough, Tuftonboro and Wolfeboro) 2005 Non-Technical Summary

Water quality data were collected by the Lake Winnipesaukee – Moultonborough and Tuftonboro volunteer monitors between May 1 and September 30, 2005 while a more in-depth water quality survey of the 20 Mile Bay and the Melvin Bay sampling stations was conducted by the **Center for Freshwater Biology** on August 23, 2005 to augment the volunteer monitoring data. The 2005 water quality generally remained within the range of values considered typical of an unproductive New Hampshire lake as summarized in Table 6. The water transparency was moderate to high while the amount of microscopic plant "algal" growth was generally low and the total phosphorus (nutrient) concentrations were generally low to moderate. However, there is a gradient of diminishing water quality (characterized by decreasing water transparency and increasing microscopic plant "algal" concentrations) from the 20 Mile Bay sampling station in Tuftonboro to the northernmost sampling location in Greens Basin (Figures 39 & 40).

Table 6: 2005 Lake Winnipesaukee – Moultonborough and Tuftonboro Seasonal Average Water Quality Readings and Water Quality Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Parameter	Oligotrophic "Pristine"	Mesotrophic "Transitional"	Eutrophic "Enriched"	Lake Winnipesaukee Average (range)	Lake Winnipesaukee Classification
Water Clarity (meters)	> 4.0	2.5 - 4.0	< 2.5	4.8 meters (range: 2.6 – 8.0)	Oligotrophic
Chlorophyll a (ppb)	< 3.0	3.0 - 7.0	> 7.0	2.0 ppb (range: 0.2 – 6.7)	Oligotrophic
Phosphorus (ppb)	< 15.0	15.0 - 25.0	> 25.0	8.8 ppb (range: 2.5 – 48.1)	Oligotrophic

The sampling locations located in Lake Winnipesaukee (Towns of Tuftonboro and Moultonborough) were characterized by similar or less clear waters in 2005, relative to the levels documented during the 2004 sampling season (Figures 27, 29, 31, 33, 35, and 37). A review of the 2005 chlorophyll *a* concentrations indicated that the median algal concentrations were near or below the 2005 concentrations at the Lake Winnipesaukee Sampling locations (Figures 28, 30, 32, 34, 36 and 38).

Water quality data collected in the vicinity of Alton Bay, Center Harbor, Long Island, Meredith Bay and Moultonborough Bay were compared to discern regional water quality variations within Lake Winnipesaukee (Figures 41 & 42). The 2005 median Moultonborough Bay water transparency of 15.5 feet (4.7 meters) was the shallowest measurement on record when compared to other regional Lake Winnipesaukee locations while the median microscopic plant (algal) concentration of 1.6 micrograms per liter (*ug/l*) documented in the Moultonborough Bay was about average for the region (Figures 41 & 42).

The following section discusses the 2005 and historical Lake Winnipesaukee water quality data that were documented in the Towns of Moultonborough and Tuftonboro. *Refer to Appendix A for a complete listing of the 2005 Moultonborough Bay water quality data and refer to Appendix B for a description of the box and whisker plots (Figures 27 – 42) that are included in the 2005 Moultonborough Bay report.*

1) Water Clarity (measured as Secchi Disk transparency) – The 2005 Lake Winnipesaukee Secchi Disk transparency measurements were consistently visible deeper than 8.3 feet (2.5 meters) that is considered the boundary between a moderately nutrient enriched "transitional" and a highly nutrient enriched lake (Figures 13 - 26). Water transparency measurements were highly variable among the seven sampling stations (Table 7 and Figure 39). The shallowest water transparency measurements were documented in Greens Basin, while the water transparency measurements documented in 19 Mile Bay included some of the shallower readings measured during the 2005 sampling season (Table 7 and Figure 39). On the other hand, extremely clear water was documented at 49 Greens Boathouse sampling site relative to the other sampling locations located in the Towns of Moultonborough and Tuftonboro.

Table 7: 2005 Water Clarity data summary for the Lake Winnipesaukee deep sampling stations.

Lake	Average Secchi Disk Transparency (meters)
Greens Basin	3.5 meters (range: 2.6 – 4.7 meters)
3 Langdon Cove	5.3 meters (range: 4.2 – 6.6 meters)
5 Melvin Bay	4.7 meters (range: 3.5 – 5.8 meters)
19 Mile Bay A	4.2 meters (range: 3.5 – 5.0 meters)
19 Mile Bay B	4.3 meters (range: 3.5 – 5.0 meters)
20 Mile Bay	6.2 meters (range: 5.0 – 8.0 meters)
49 Greens Boathouse	7.4 meters (range: 6.5 – 8.0 meters)

2) Microscopic plant abundance "greenness" (measured as chlorophyll *a*) – The 2005 Moultonborough Bay seasonal chlorophyll *a* measurements remained below the concentration of 7.0 parts per billion (ppb) that is considered the boundary between a moderately productive "transitional" and a highly productive New Hampshire Lake (Table 8). The seasonal average chlorophyll *a* concentrations

Table 8: 2005 Chlorophyll *a* data summary for the Lake Winnipesaukee deep sampling stations.

Lake	Average Chlorophyll *a* Concentrations (ppb)
Greens Basin	4.3 ppb (range: 2.8 – 6.7 ppb)
3 Langdon Cove	2.5 ppb (range: 1.9 – 4.3 ppb)
5 Melvin Bay	1.8 ppb (range: 0.8 – 3.0 ppb)
19 Mile Bay A	0.9 ppb (range: 0.2 – 2.9 ppb)
19 Mile Bay B	1.0 ppb (range: 0.2 – 2.4 ppb)
20 Mile Bay	1.6 ppb (range: 1.3 – 2.5 ppb)
49 Greens Boathouse	1.7 ppb (range: 0.9 – 2.6 ppb)

were highly variable among the seven sampling stations; the least amount of algal growth was documented in 19 Mile Bay and, as in the past, the highest chlorophyll *a* concentration (i.e. greenest water) was documented in Greens Basin (Table 8 and Figure 40).

The 2005 median chlorophyll *a* concentration documented in Langdon Cove, 19 Mile Bay (B) and 49 Greens Boathouse were similar to the 2004 median concentrations (Figures 28, 30 & 36) while the 2005 median chlorophyll *a* concentrations documented at Sites 5 Melvin Bay, 19 Mile Bay (A) and 20 Mile Bay sampling locations decreased relative to the 2004 levels (Figures 32, 34 & 38). The 2005 chlorophyll *a* concentrations remained below nuisance concentrations at all sampling locations.

3) Background (dissolved) water color: often perceived as a "tea" color in more highly stained lakes – The 2005 dissolved color concentration, spanning Moultonborough, Tuftonboro and Wakefield, averaged 18.9 chloroplatinate units (cpu) and fell within the classification of a slightly colored lake (Table 9). Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. The highest dissolved color concentrations were documented in Greens Basin and likely have some influence on the shallower water transparency measurements documented at the northernmost sampling location..

Table 9. Dissolved Color Classification Criteria used by the New Hampshire Lakes Lay Monitoring Program.

Range	Classification
0 - 10	Clear
10 - 20	Slightly colored
20 - 40	Light tea color
40 - 80	Tea colored
> 80	Highly tea colored

4) Total Phosphorus: the nutrient considered most responsible for elevated microscopic plant growth in our New Hampshire Lakes. – The 2005 total phosphorus concentrations were generally low and ranged from 2.5 to 48.1 parts per billion (ppb) in the surface waters. With the exception of significantly elevated total phosphorus concentrations on July 13 and July 20, 2005, the remaining total phosphorus remained below the concentration of 15 ppb that is considered the boundary between an unproductive and a moderately productive New Hampshire lake. *Note: neither of the elevated total phosphorus samples documented in mid-July coincided with chlorophyll a spikes that are commonly associated with relatively high total phosphorus concentrations.*

5) Resistance against acid precipitation (measured as total alkalinity) – The 2005 alkalinity measured 7.1 milligrams per liter (mg/l) and remained within the range considered typical of a lake with a moderate vulnerability to acid precipitation according to the standards developed by the New Hampshire Department of Environmental Services (Table 10). Generally speaking, the geology of the region does not contain the mineral content (e.g. limestone) which increases the buffering capacity in our surface waters. Thus, lakes in the vicinity (e.g. Mirror Lake and Squam Lake) have naturally low alkalinities. While low, the Lake Winnipesaukee alkalinity remained sufficient to buffer against acid inputs and to avoid large pH fluctuations that are stressful to most aquatic organisms.

Table 10. Alkalinity Classification Criteria used by the New Hampshire Department of Environmental Services

Range (mg/L)	Classification
< 0	Acidified
0 -2	Extremely Vulnerable
2.1 - 10.0	Moderately Vulnerable
10.1 - 25.0	Low Vulnerability
> 25.0	Not Vulnerable

Lake acidity (measured as pH) – The 2005 pH data, collected in the surface waters by the **Center for Freshwater Biology**, ranged from 7.2 to 7.3 units at Sites 5 Melvin Bay and 20 Mile Bay and remained well within the tolerable range for most aquatic organisms.

6) **Dissolved salts: measured as specific conductivity** – Specific conductivity levels measured by the **Center for Freshwater Biology** were moderate and ranged from 69.4 to 75.1 micro-Siemans (*u*S) when measured in Melvin Bay and 20 Mile Bay on August 23, 2005. High specific conductivity values can be an indication of problem areas around a lake where failing septic systems, heavy fertilizer applications and sedimentation are contributing "excessive" nutrients into the lake. High conductivity concentrations can also be an indication of heavy road salt runoff into the lake.

7) **Temperature and dissolved oxygen profiles** – Temperature profiles collected by the volunteer monitors indicate Lake Winnipesaukee becomes stratified into three distinct thermal layers during the summer months. A warm upper water layer, the **epilimnion**, overlies a deep cold-water layer, the **hypolimnion.** The upper and lower zones are separated by a **third** layer of rapidly decreasing temperatures referred to as the **metalimnion** or the **thermocline.** The formation of thermal stratification limits the replenishment of oxygen into the deeper waters and under adverse conditions can be associated with oxygen depletion near the lake bottom.

Dissolved oxygen concentrations required for a healthy fishery – dissolved oxygen concentrations, measured by the **Center for Freshwater Biology** on August 23, 2005, remained near or above 5 milligrams per liter (mg/L) down to approximately 9.0 meters in 20 Mile Bay and remained above 5 milligrams per liter down to the lakebottom in Melvin Bay (Figure 43). A dissolved oxygen concentration of 5 milligrams per liter is commonly considered the minimum oxygen concentration required for the successful growth and reproduction of most coldwater fish that include rainbow trout and salmon. Historical water quality data collected north into Greens Basin indicate the dissolved oxygen concentrations become depleted at most of the deep sampling locations located in the Moultonborough Neck/Moultonborough Bay segment of the lake. The depleted dissolved oxygen concentrations characteristic of the Moultonborough Bay region likely restrict the coldwater fish population to other portions of the lake during the warm summer months.

8) Based on the current and historical water quality data, Moultonborough Bay would be considered a moderately nutrient enriched "transitional" segment of Lake Winnipesaukee. A first step towards preserving the high water quality in Lake Winnipesaukee is to take action at the local level and do your part to minimize the number of pollutants (particularly sediment and the nutrient phosphorus) that enter the lake. Whenever possible, **maintain riparian buffers** (vegetative buffers adjacent to the water body). These buffers will biologically "take up" nutrients before they enter the lake and will also provide physical filters which allow materials to settle out before reaching the lake. **Reduce fertilizer applications**. Most residents apply far more fertilizers than necessary which can be a costly expense to the homeowner and can also be detrimental to the lake since the same nutrients that make our lawns green will also stimulate plant growth in our lakes. **Make sure your septic system is well maintained.** Have your septic system pumped out on a regular basis. An improperly functioning septic system can contribute "excessive" nutrients into the lake and can result in early failure, costing thousands of dollars to repair or replace.

It is also important to make sure the watershed residents are well-educated on water quality related issues. Numerous publications are available through the University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services as well as several other local, state and federal agencies. It is imperative that future activities within the Lake Winnipesaukee watershed are carefully thought out before implementation if water quality degradation is to be minimized. *Refer to the "Comments and Recommendations" section for more detailed suggestions.*

COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating volunteer monitoring entity, including the Lake Winnipesaukee and the Towns of Tuftonboro and Moultonborough, continue to develop its database on lake water quality through continuation of the long-term monitoring program. The database currently provides information on the short-term and long-term cyclic variability that occurs in Lake Winnipesaukee and through continued monitoring would enable more reliable predictions of both short-term and long-term water quality trends.

2) We recommend continued lake sampling early in the season (April/May) to document Lake Winnipesaukee's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color and Secchi Disk transparency measurements. The collection of phosphorus samples are also recommended from both the in-lake and the tributary sampling sites. Whenever possible, water quality samples should be collected on a frequent "weekly" basis that is necessary to assess the current condition of Lake Winnipesaukee.

3) The Lake Winnipesaukee Association has completed a two year tributary sampling program that involved the collection of water samples at the Lake Winnipesaukee tributary inlets during the summers of 2004 and 2005; the project was funded through an Environmental Protection Agency grant that was administered through the New Hampshire Department of Environmental Services. Two of the sampling locations are located in the Town of Moultonborough (Lake Kanasatka Outlet and HalfWay Brook) while four tributary sampling locations are located in Tuftonboro (Nineteen Mile Brook, Twenty Mile Brook, Melvin River and Copp's Brook). The results of the Lake Winnipesaukee tributary monitoring program has been summarized in a report titled, <u>Tributary Monitoring in the Winnipesaukee Watershed: A Final Report to the New Hampshire Department of Environmental Services</u>, that is currently available for viewing online at http://www.winnipesaukee.org/pdf/WinTribRep06.pdf.

4) Local road associations, homeowners associations and conservation commissions might consider expanding the 2005 volunteer monitoring effort to include near-shore sampling locations that will better assess whether or not localized water quality problems exist. Near-shore water quality monitoring could include the collection of total phosphorus and microscopic plant "algal" samples that will reflect local variations in nutrient loading and local variations in the resulting algal growth "greenness". There are also different types of electronic instruments such as turbidity and conductivity meters that can be useful for screening and identifying potential "hot spots" around the lake. Should potential problem areas be identified, future educational and remedial efforts could be focused on those priority regions. Should you want to discuss potential water quality monitoring strategies further please contact Bob Craycraft at 862-3696 or via email at bob.craycraft@unh.edu.

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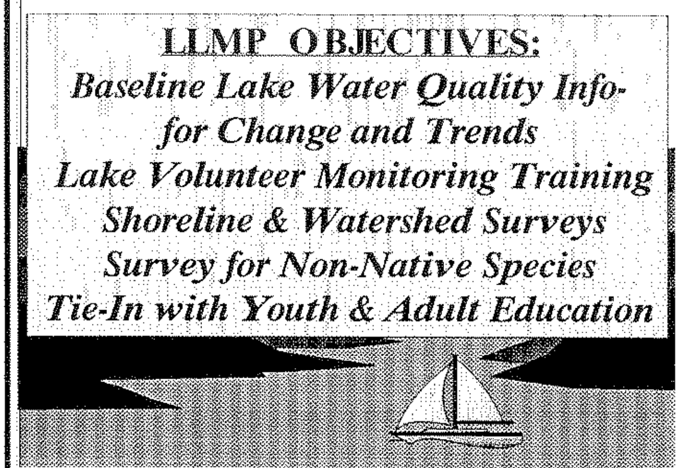
INTRODUCTION

The New Hampshire Lakes Lay Monitoring Program

The 2005 sampling season marked the twenty-seventh anniversary for the NH **Lakes Lay Monitoring Program (LLMP).** The LLMP has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a database for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

Figure 1. LLMP Objectives



The **NH LLMP** has gained an international reputation as a successful cooperative monitoring, education and research program. Current projects include: the use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), and intensive watershed monitoring for the development of watershed nutrient budgets, investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative cost share funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 2005 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program.** National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Table 11).

Table 11. Awards & Recognition

1983-	NH Environmental Law Council Award
1984-	GoOvernor's Volunteer Award
1985-	CNN Science & Technology Today
1988-	Governor's "Gift" award funded
1990-	NH Journal TV coverage NHPTV
1991-	Renew America Award
	Environmental Success Index
	White House Reception / Briefing
1992-	EPA Administrators Award
	Environmental Exchange Network Listing
1993-	NH Lakes Association Award
1994-	EPA Office of Watersheds Award
1995-	Winnipesaukee Watershed Project
1998-	Governor's Proclamation for 20th Anniversary
1999-	EPA Watershed Academy Host
2001-	Lake Chocorua Project highlighted at national conferences (invited presentations)
2002-	Chocorua Project receives Technical Excellence Award from the North American Lake Management Society
2003-	UNH CE Maynard and Audrey Heckel Extension Fellowship awarded to LLMP
2004-	Participatory Research Model of NH LLMP highlighted at National Water Quality Monitoring Conference
2005-	LLMP Coordinator J. Schloss receives the prestigious Secchi Disk Award from the North American Lakes Management Society

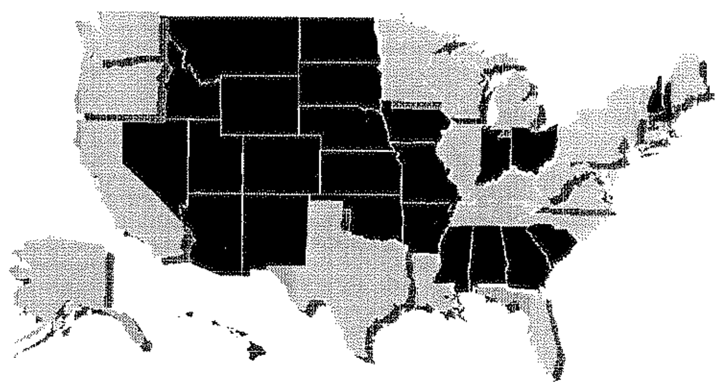
We are excited by the results of teaming up students, educators and local lake residents through our Multidisciplinary Lakes Management course and our summer Community Mapping with GIS and Watershed Ecology courses that are held annually (the two latter mentioned courses are for educators, community leaders and other interested persons). Some of the lake management recommendations made as part of the student coursework requirements have been successfully implemented by lake associations.

Our active collaboration with the UNH Center for Freshwater Biology continues to drive relevant applied research: Our volunteer intensive Water / Nutrient Budget Study of the Squam Lakes Watershed has provided insights into the impacts of development, growth and septic systems on lake water quality. Combined with the knowledge gained from the Lake Chocorua Watershed Study we are closer to understanding what the level of nutrient conditions we can expect from different land uses.

We have also been a key player in testing an integrated pest management approach (see our "Special Topic" in this report) to exotic variable water milfoil control and have also recently initiated a study examining the potential to manage exotic milfoil growth using parasitic nematodes.

Figure 2. National LLMP Support to Volunteer Monitoring Programs

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 24 States.



Light gray shading denotes LLMP assisted states

We continue the research initiated by collaborators Dr. John Sasner and Dr. Jim Haney focusing on how watershed development and our activities on the landscape play a role in creating potentially toxic algae blooms. Analogous to the 'red tide" of estuaries, certain blue-green algae (microscopic bacteria) can produce toxins that are heath risks to animals and humans.

Additional ongoing research is focusing on the use of satellite imagery as well as on-lake optical devices as a means of determining the water transparency and amount of microscopic plant "algal" growth in our New Hampshire Lakes, particularly blue green algae. Water quality data, collected by the volunteer monitors, have served as ground truthed data to assess whether or not the satellite imagery shows promise. Data generated through this project have been presented at national conferences and are testament to the high quality data generated by our volunteer monitors.

Recent interest in the success of our NH LLMP participatory research model has resulted in invited presentations at national conferences and provided the basis of a series of articles in the Volunteer Monitor, the national newsletter with a distribution of over 10,000.

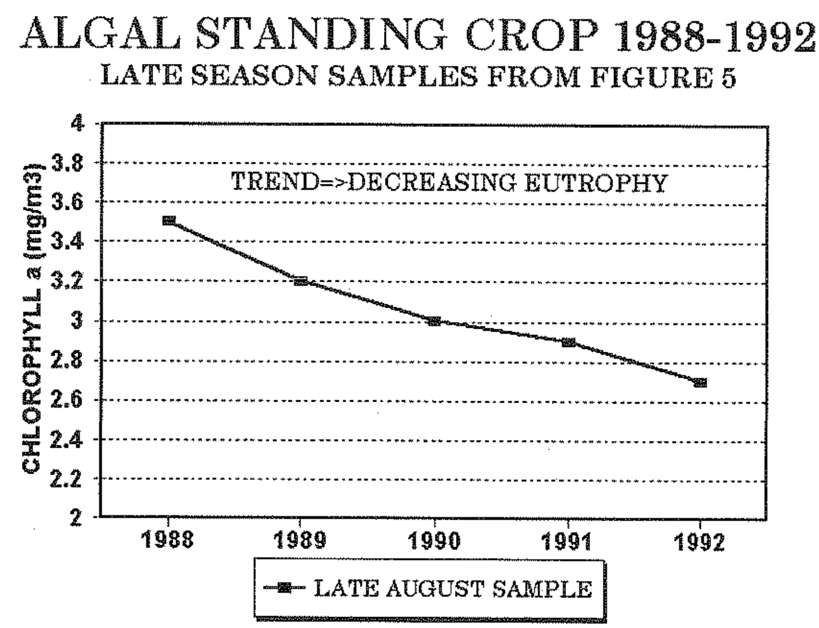
We continue to be listed as a model citizen-monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability. To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty-four states and eleven countries (Figure 2)!

Importance of Long-term Monitoring

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For over two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

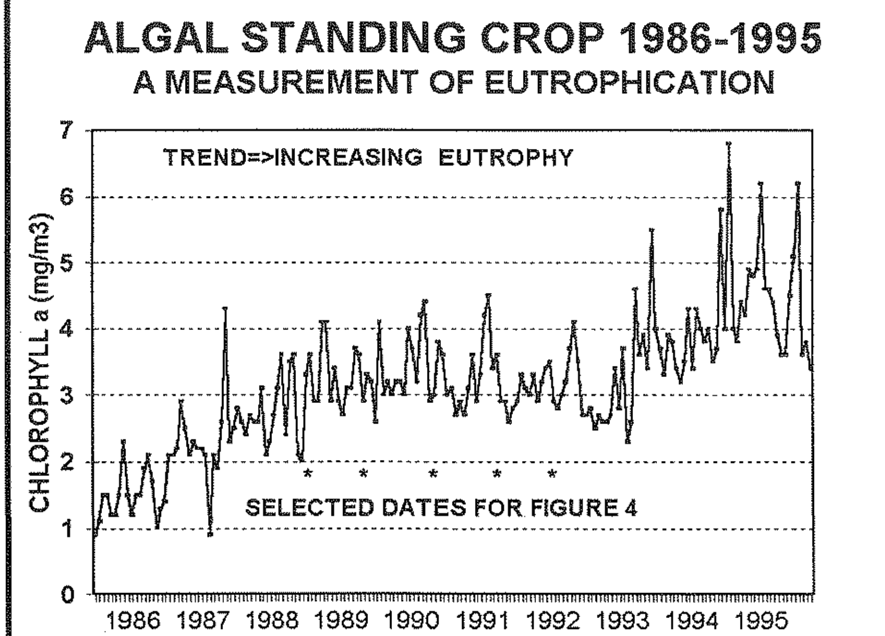
Figure 3.



Consider the hypothetical data depicted in Figure 3. Limiting sampling to only once a year during August, from 1988 to 1992, produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" could only be accomplished through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term database will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

Figure 4



There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program.** Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

Purpose and Scope of This Effort

2005 was the twenty-third year that water quality monitoring of Lake Winnipesaukee was undertaken in conjunction with the **NH Lakes Lay Monitoring Program (NH LLMP).** The monitoring program is designed to establish a long-term database to which future data could be compared and to identify localized problem areas where future educational and corrective efforts should be focused. Sampling emphasis was placed on 7 open water sampling stations in the Towns of Moultonborough and Tuftonboro while additional tributary sampling was also undertaken at select tributary inlets into Lake Winnipesaukee.

The primary purpose of annual lake reporting is to discuss results of the current monitoring season with emphasis on current conditions of New Hampshire lakes including the extent of eutrophication and the lakes' susceptibility to increasing acid precipitation. If there are additional water quality concerns we advise the lake association to contact our program staff to discuss additional monitoring options. When applicable we also strive to place the recent results into a historical context using past NH LLMP data as well as historical data from other sources. This information is part of a large data base of historical and more recent data compiled and entered onto our computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **CFB/FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

Climatic Summary - 2005

Water Quality and the Weather

Water quality variations are commonly observed over the course of the year and among years in our New Hampshire lakes, ponds, wetlands and streams. The most commonly noticed changes are those associated with decreasing water clarities, increasing algal growth (greenness), and increasing plant growth around the lake's periphery. Over the long haul, changes such as these are attributed to a lake's natural aging process; what is known as **"eutrophication"**. However, short-term water quality changes such as those mentioned above are often encountered even in our most pristine lakes and ponds. These water quality changes often coincide with variations in weather patterns that include precipitation and temperature fluctuations and even variations in the sunlight intensity that can accelerate or suppress the photosynthetic process.

Climatic "swings" can have a profound effect on water quality, sometimes positive and other times negative. For instance, 1996 was a wet year relative to other years of **LLMP** water quality monitoring. This translated into reduced water clarities, elevated microscopic plant "algal" growth and increased total phosphorus concentrations for most participating **LLMP** lakes. "Excessive" runoff associated with wet periods often facilitates the transport of pollutants such as nutrients (including phosphorus), sediment, dissolved colored compounds, as well as toxic materials such as herbicides, automotive oils, etc. into water bodies. As a result, lakes often respond with shallower (less clear) water clarities and elevated algal abundance "greenness" during these periods as evidence by historical monitoring through the **NH LLMP**. Similarly, short-term storm events can have a profound effect on the water quality. Take for instance the "100 year storm" (October 21-22, 1996) that blanketed southern New Hampshire with approximately 6 inches of rain over a 30-hour period. This storm resulted in increased sedimentation and organic matter loading into our lakes as materials were flushed into the water bodies from the adjacent uplands. Likewise, the heavy rains that saturated the soil and resulted in flood conditions in June 1998 (heaviest rains occurring on June 12 and 13) resulted in significantly shallower water transparency readings in the weeks to months that followed. While events such as the October 1996 and the June 1998 storms are short lived, they can have a profound effect on our water quality in the weeks to months that follow, particularly when nutrients that stimulate plant growth are retained in the lake.

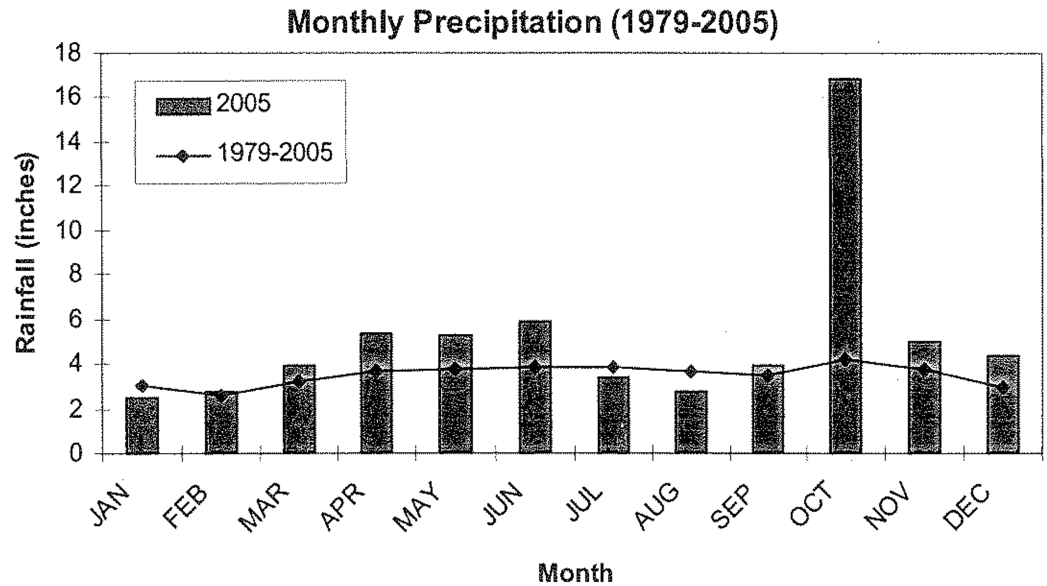
NH LLMP data collected during dry years such as 1985 and 2001, on the other hand, have coincided with improved water quality for many New Hampshire lakes. Reduced transport of pollutants into the lake often results in higher water quality measured as deeper water transparencies, lower microscopic plant "algae" concentrations and lower nutrient concentrations. Do all lakes experience poorer water quality as a result of heavy precipitation events? Simply stated, the answer is no. While most New Hampshire lakes are characterized by reduced water clarities, increased nutrients and elevated plant "algal" concentrations following periods, or years, of heavy precipitation, a handful of lakes actually benefit from these types of events. The water bodies that improve during wet periods are generally lakes characterized by high nutrient concentrations and high "algal" concentrations that are diluted by watershed runoff and thus benefit during periods, or years, of heavy rainfall. However, these more nutrient enriched lakes remain susceptible to nutrients entering the lake from seepage sources such as poorly functioning septic systems.

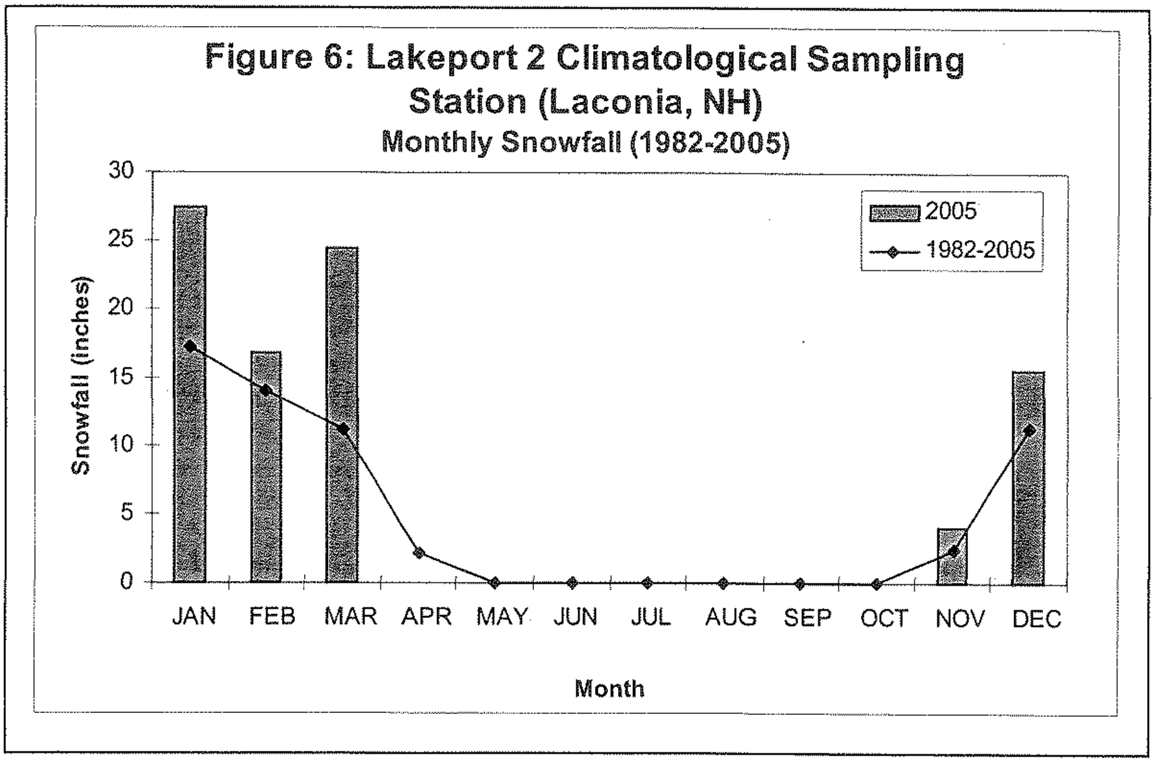
Precipitation (2005)

The 2005 annual precipitation (reported as "rainfall" water equivalent) measured 61.94 inches and was the highest "rainfall" amount that has been documented over the past 27 years: 1979-2005 (note: precipitation data are reported for the Lakeport 2 Climatological sampling station located in Laconia New Hampshire: 43°33'N and 71°28'W). The monthly precipitation totals documented during the months of January and February were near/below average although the timing of the rainfall events coincided with low temperatures that translated into relatively heavy periods of snowfall during January and February. The March precipitation was above average and was coupled with two snow-storms, and below average temperatures, during the first third of the month that culminated in of the additional snowpack accumulation that contributed to periods of heavy runoff later in the month of March and into the Month of May (Figures 5 & 6). Significant accumulations of winter snowpack can result in a period of heavy overland runoff in the spring that oftentimes coincides with increased sediment and nutrient loading that negatively impacts water quality. Above average rainfall continued into the month of June during which the rainfall was largely concentrated to the middle of the month. The subsequent months of July and August were characterized by below average rainfall followed by slightly above average rainfall during the month of September.

A series of storms swept through New Hampshire during the month of October during which the rainfall amount was nearly four times above the 27 year average documented between 1979 to 2005 (Figure 5). Futhermore, the October 2005 rainfall reached record levels in some locations in southern New Hampshire. The months of November and December rounded out the years with above average rainfall and above average snowfall.

Figure 5: Lakeport 2 Climatological Sampling Station (Laconia, NH)



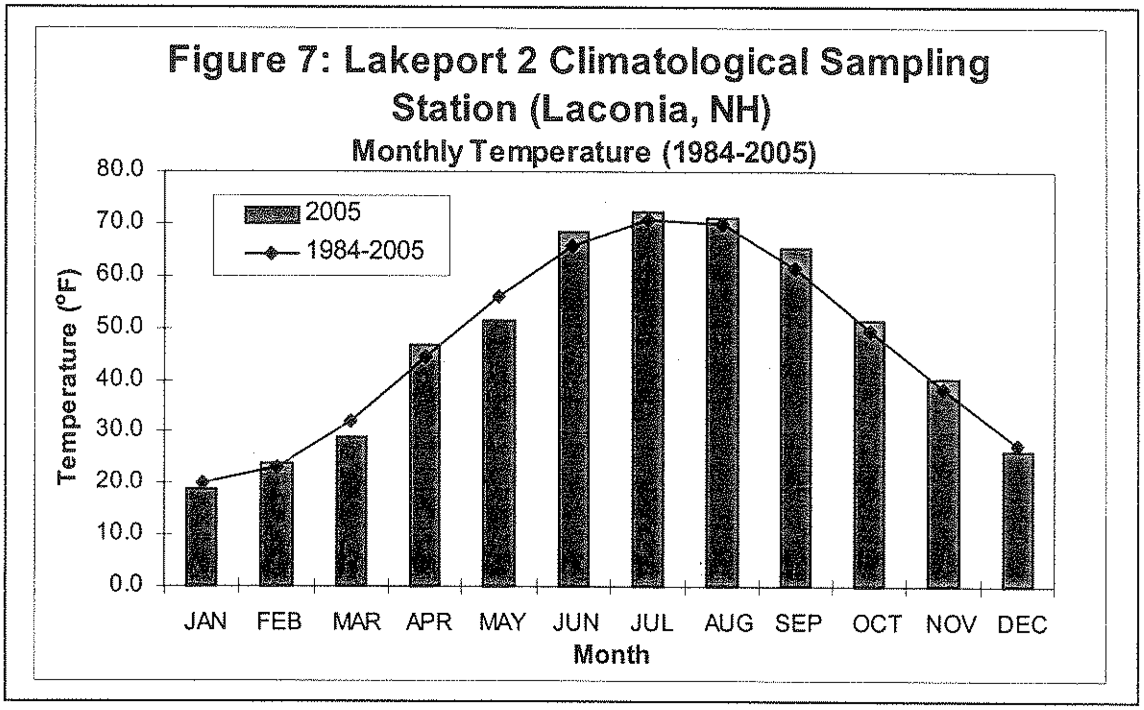


Temperature (2005)

Similar to the impact of precipitation extremes, temperature extremes can have far reaching effects on the water quality, particularly early in the year and during the summer months. Atypically warm spells can account for a rapid snowpack melt resulting in flooding and a massive influx of materials (e.g. nutrients, sediments) into our lakes during the late winter and early spring months. Early spring runoff periods coincide with minimal vegetative cover (that acts as a pollutant filter and soil stabilizer) and thus leaves the landscape highly susceptible to erosion. As we progress into the summer months, atypically warm periods can enhance both microscopic "algal" and macroscopic aquatic "weed" plant growth. During the summer growing season, above average temperatures often result in algal blooms that can reach nuisance proportions under optimal conditions. These nuisance blooms can include surface algal "scums" that cover the lake and wash up on the windward lakeshores.

During years such as 1994 and 1995, when above average temperatures characterized the summer months, participating **NH LLMP** lakes were generally characterized by increased algal concentrations, particularly in the shallows, where filamentous cotton candy like clouds of algae (i.e. *Mougeotia*) flourished. Other **NH LLMP** lakes had increased algal growth "greenness" and shallower water transparencies during these "hot" periods.

The January and February 2005 monthly temperatures were near the twenty two year average while the March, 2005 temperature was approximately 3°F below the 22 year average (Figure 7). Increasing temperatures and above average rainfall during the months of April and May contributed to periods of heavy spring runoff. The monthly temperature averages documented between April and December 2005 oscillated from near average temperatures to slightly above or slightly below average tem-



peratures (Figure 7). Below average temperatures during the month of May (over four °F below the twenty two year average) corresponded to some of the colder in-lake water temperatures documented in recent years through the month of June. The below average water temperatures that were documented into June might have suppressed some of the microscopic plant "algal" and macroscopic plant growth early in the 2005 sampling season.

Water Quality Impacts

Water Transparency and Dissolved "tea" Colored Water

As previously mentioned shallower water transparency readings are characteristic of most New Hampshire lakes during wet years and following short term precipitation events. Wet periods often coincide with greater concentrations of dissolved "tea" colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes. Data collected by the **Center for Freshwater Biology (CFB)** since 1985 indicate most lakes are characterized by higher dissolved "tea" colored water during wet years relative to years more typical in terms of annual precipitation levels. In some of our more highly "tea" colored lakes the early spring months are also characterized by higher dissolved color concentrations, relative to mid-summer levels, due to the heavy runoff periods that flush highly colored water into our lakes during the period of spring snowmelt and following heavy spring rains.

Sediment Loading

Sediments are continuously flushed into our lakes and ponds during periods of heavy watershed runoff, particularly during snowmelt and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experience water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreside buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the particulate debris and dissolved materials are flushed into the lake. Human activities such as logging, agriculture, construction and land clearing can also increase sediment displacement during and following heavy storm events throughout the year. These activities are often associated with excessive sediment loading in many of our lakes and ponds. As these materials (sediments) are transported into surface waters they can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth that can result in plant die-offs and the subsequent oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and fish spawning habitat. As the dead materials begin to decay the result can be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lakebottom; new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water milfoil (*Myriophyllum heterophyllum*) will generally regenerate more rapidly than more favorable plant forms. This can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another unfavorable attribute of sediment loading is that the sediments tend to carry with them other sorts of contaminant such as pathogens, nutrients and toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lakebottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lakebottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lakebottom you might notice a change in the weed composition reflecting a change in the substrate type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to other factors.

Nutrient Loading

Nutrient loading is often greatest during heavy precipitation events, particularly during the periods of heavy watershed runoff. Phosphorus is generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes. Elevated phosphorus concentrations are generally most visible when documented in our tributary inlets where nutrients are concentrated in a relatively small volume of water. Much of the phosphorus entering our lakes is attached to particulate matter (i.e. sediments, vegetative debris), but may also include dissolved phosphorus associated with fertilizer applications and septic system discharge.

Microscopic "Algal" and Macroscopic "Weed" Plant Growth

Historical **Lakes Lay Monitoring Program** data indicate most lakes experience "algal blooms" during years with above average summer temperatures (June, July and August) while years with heavy precipitation are also associated with an increased frequency and occurrence of "algal blooms" among participating **LLMP** lakes. Algal blooms are often green water events associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". During some years, such as 1996, the algal blooms are predominantly green water events composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with an atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices and construction activities favor the displacement of nutrients into surface waters. The occasional formation of certain algal blooms is a naturally occurring phenomenon and is not necessarily associated with changes in lake productivity. However, increases in the occurrence of bloom conditions can be a sign of eutrophication (the "greening" of a lake). Shifts from benign (clean water) forms to nuisance (polluted water) cyanobacterial forms such as *Anabaena*, *Aphanizomenon* and *Oscillatoria*, can also be a warning sign that improper land use practices are contributing excessive nutrients into the lake.

Filamentous cotton-candy like "clouds" of the nuisance green algae, *Mougeotia* and related species, have been well documented in 1994 and 1995 when the temperatures during the months of June and July were well above normal. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lakebottom and tend to flourish during warm periods. During cooler years, this type of algal growth is kept "in check" and generally does not reach nuisance proportions.

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading.

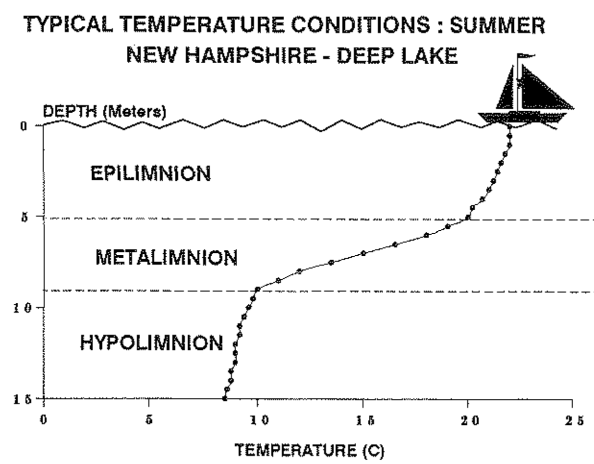
DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Certain tests or sampling performed at the time of the optional **Center for Freshwater Biology** field trip are indicated by an asterisk (*).

Thermal Stratification in the Deep Water Sites

Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (Figure 8). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

Figure 8



Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes.

Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg m^3 (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg m^3. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg m^3 and 7 mg m^3. Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below); confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lake bottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu.

Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

Streamflow

Streamflow, when collected in conjunction with depth contour information, is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Center for Freshwater Biology** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micro**mhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS).

Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

Total coliform includes all coliform bacteria that arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Blue-green bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa, rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddis flies (Trichop-tera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

Inspect your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

Flush the cooling system, bilge areas and live wells with tap water.
Leave unused bait behind and discard bait bucket water away from surface waters.
Keep your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**
Wash down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!
Learn more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.
Share information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group and or civic organization.
Report any sightings to the **New Hampshire Lakes Lay Monitoring Program**. Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

Jeff Schloss
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38 College Road   Room 133 Spaulding Hall
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(603) 862-3848

UNIVERSITY *of* NEW HAMPSHIRE
COOPERATIVE EXTENSION

Understanding Lake Aging (Eutrophication)

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A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algae" growth (detected as greener water), and water transparency decreases; what is known as **eutrophication**. Eutrophication is a natural process by which all lakes age and progress from clear, pristine lakes to green, nutrient enriched lakes on a geological time frame of thousands of years. Much like the fertilizers applied to our lawns, nutrients that enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to naturally occurring attributes: watershed area relative to lake area, slope of the land surrounding the lake, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age which ended about 10,000 years ago, we should have a natural continuum of lakes ranging from extremely pristine to very enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake plant and algae productivity or "greenness" Refer to Table 12 below for a summary of commonly used eutrophication parameters.

Table 12: Eutrophication Parameters and Categorization

Parameter	Oligotrophic "pristine"	Mesotrophic "transitional"	Eutrophic "enriched"
Chlorophyll a (*ug*/l) *	<3.0	3.0-7.0	>7.0
Water Transparency (meters) *	>4.0	2.5-4.0	<2.5
Total Phosphorus (*ug*/l) *	<15.0	15.0-25.0	>25.0
Dissolved Oxygen (saturation) #	high to moderate	moderate to low	low to zero
Macroscopic Plant (Weed) Abundance	low	moderate	high

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
 # Denotes dissolved oxygen concentrations near the lakebottom.

Oligotrophic lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lake bottom. **Eutrophic** lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands of aquatic plants and very low dissolved oxygen concentrations near the lake bottom. **Mesotrophic** lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lake bottom.

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily! As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due to their natural attributes and in turn have aged more rapidly. This is not necessarily a bad thing as our best bass fishing lakes tend to be more mesotrophic to eutrophic than oligotrophic; an ultra-oligotrophic lake (extremely pristine) will not support a very healthy cold water fishery. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period that should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of once forested or agricultural lands are being developed, with the potential for increased sediment and nutrient loadings into our lakes which augment the eutrophication process.

Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". A "healthy" lake, as far as eutrophication is concerned, is one in which the various aquatic plants and animals are minimally impacted so that nutrients and other materials are processed efficiently. We can liken this process to a well-managed pasture: nutrients stimulate the growth of grasses and other plants that are eaten by grazers like cows and sheep. As long as producers and grazers are balanced, a good amount of nutrients can be processed through the system. Impact the grazers and the grass will overgrow and nuisance weeds will appear, even if nutrients remain the same. In a lake, the producers are the algae and aquatic weeds while the grazers are the microscopic animals (**zooplankton**) and aquatic insects. These organisms can be very susceptible to a wide range of pollutants at very low concentrations. If impacted, the lake can become much more productive and the fishery will be impacted as well since these same organisms are an important food source for most fish at some stage of their life.

Development upon the landscape can negatively affect water quality in a number of ways:

- <u>Removal of shore side vegetation and loss of wetlands</u> - shore side vegetation (what is known as **riparian vegetation**) and wetlands provide a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed and wetlands lost, pollutant materials are more likely to enter the lake and in turn, favor declining water quality.

- <u>Excessive fertilizer applications</u> - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline producing unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are dangerous when ingested.

- Increased organic matter loading - organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.

- Septic problems - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.

- Loss of vegetative cover and the creation of impervious surfaces - A forested watershed offers the best protection against pollutant runoff. Trees and tall vegetation intercept heavy rains that can erode soils and surface materials. The roots of these plants keep the soils in place, process nutrients and absorb moisture so the soils do not wash out. Impervious surfaces (paved roads, parking lots, building roofs, etc.) reduce the water's capacity to infiltrate into the ground, and in turn, go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify pollutants and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities that favor the transport of a greater load of suspended and dissolved pollutants into your lake.

How can you minimize your water quality impacts?

- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess eventually draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody in the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake. Have your soil tested for a nominal fee (contact your county UNH Cooperative Extension Office for further information) to find out how much fertilizer and soil amendments and really needed. Sometimes just an application of crushed lime will release enough nutrients to fit the bill. If you do use fertilizer try to use low phosphorus, slow release nitrogen varieties. And remember that under the current NH Comprehensive Shoreline Protection Act (CSPA) you cannot apply any fertilizers or amendments within 25 feet of the shore.
- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center. Do not fill in wetland areas. Do not create or enhance beach areas with sand (contains phosphorus, smothers aquatic habitat, fills in lake as it gets transported away by currents and wind).

- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Refer to:

  Septic Systems, How they work and how to keep them working. $1.00/ea University of New Hampshire Publications Center (603) 862-2346

  Pipeline: Fall 1994 Vol. 15, No. 4. Maintaining Your Septic System-A Guide for Homeowners. http://www.nesc.wvu.edu/nsfc/pdf/pipline/PL_fall04.pdf1

- Try to landscape and re-develop with consideration of how water flows on and off your property. Divert runoff from driveways, roofs and gutters to a level vegetated area or a rain garden so the water can be slowed, filtered and hopefully absorbed as recharge. Refer to:

  A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water. North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1,. Meredith NH 03253-9266 (603) 279-6546

- Maintain shore side (riparian) vegetative cover when new construction is undertaken. For those who have pre-existing houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Refer to:

  Planting Shoreland Areas (no charge) University of New Hampshire Cooperative Extension Publication Center. (603) 862-2346

  A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water. North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1,. Meredith NH 03253-9266 (603) 279-6546

  Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire. 3 Silk Farm Road, Concord NH 03301 (603) 224-9909 (free for towns, $5.00 for others).

- Review the New Hampshire Comprehensive Shoreland Protection Act (CSPA) if you have shoreland property. The CSPA sets legal regulations aimed at protecting water quality. If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator at* (603) 271-3503.

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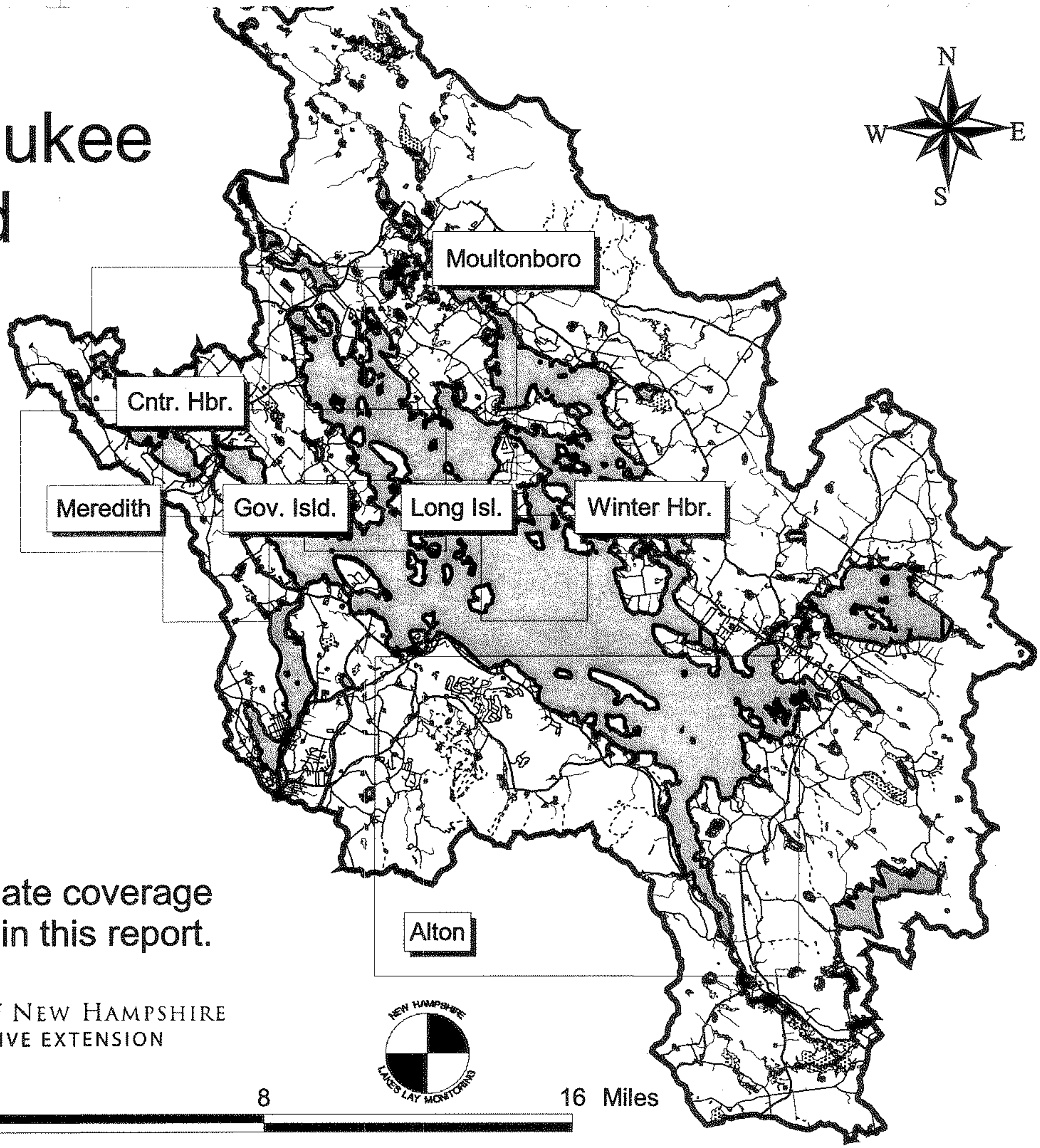
REPORT FIGURES

Figure 9. Map of the Lake Winnipesaukee Watershed. *Refer to Figures 10, 11 and 12 for detailed maps of the current and proposed Moultonborough and Tuftonboro sampling stations.*

Winnipesaukee Watershed



Map shows approximate coverage of sitemaps included in this report.

UNIVERSITY *of* NEW HAMPSHIRE
COOPERATIVE EXTENSION

NEW HAMPSHIRE LAKES LAY MONITORING

8 0 8 16 Miles

Figure 10. Location of the year 2005 Lake Winnipesaukee Langdon Cove and Moultonborough Bay sampling stations.

Moultonborough Bay Area

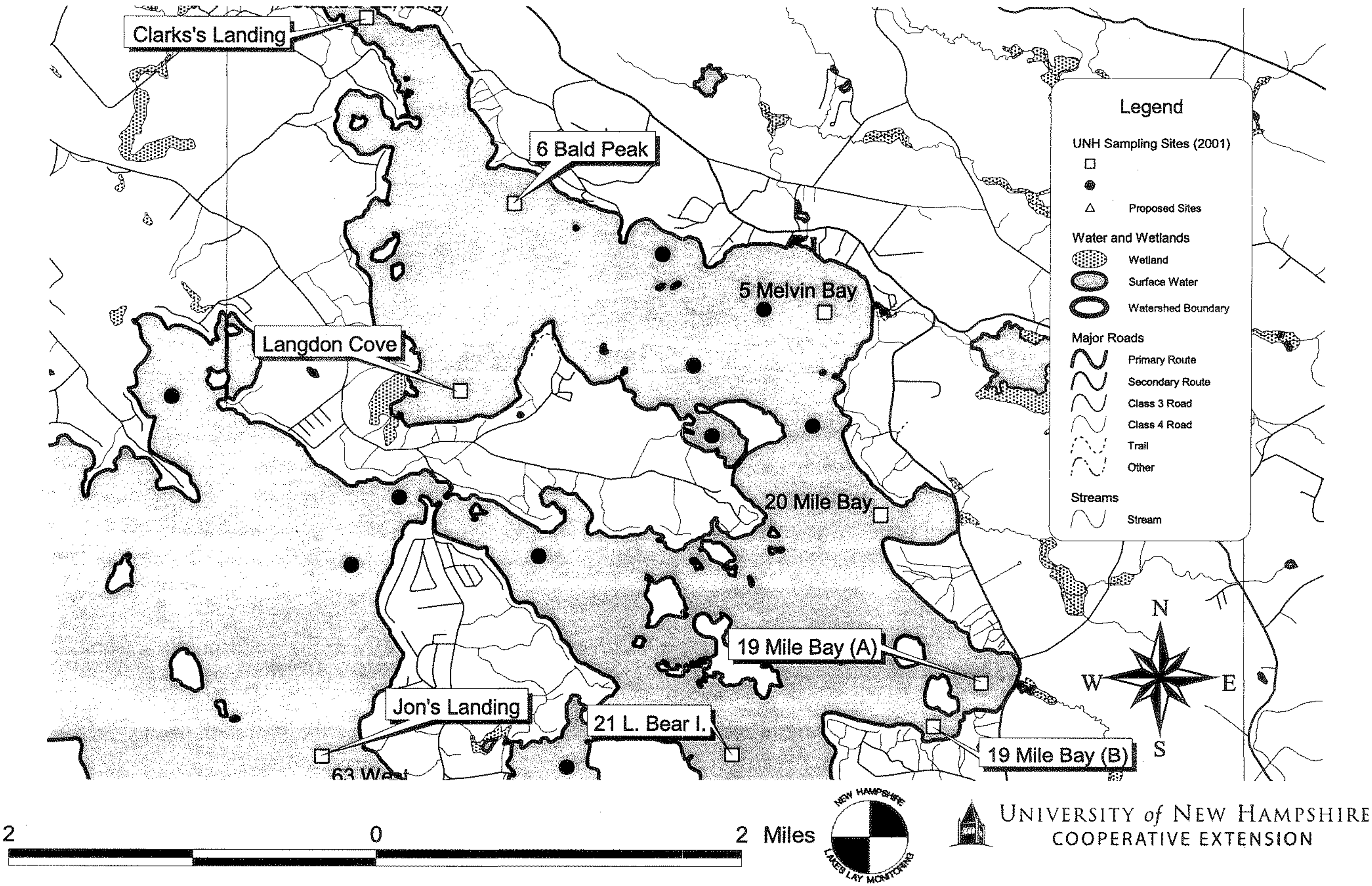


Figure 11. Location of the year 2005 Lake Winnipesaukee Long Island sampling station, Site 49 Greens Boathouse.

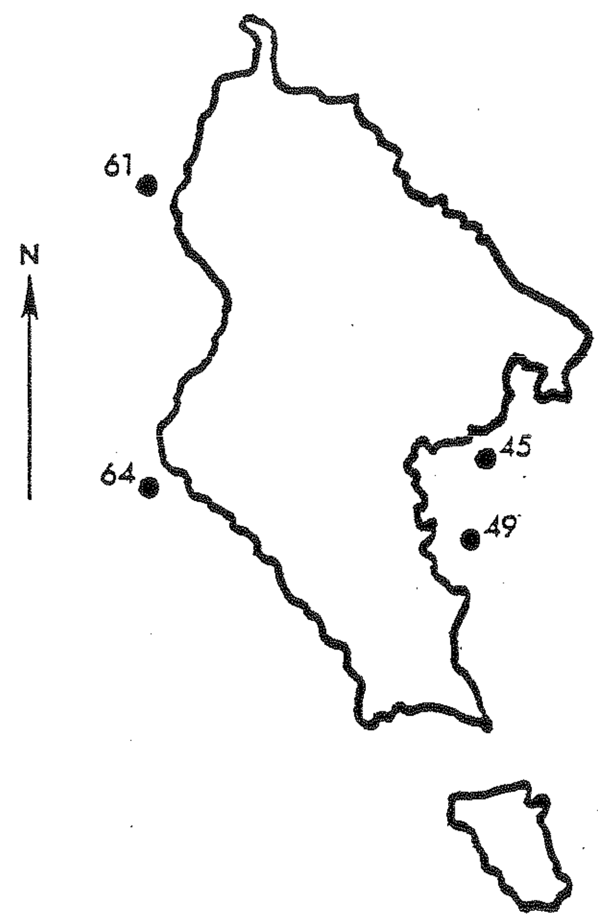

N
61
64
45
49

Figure 12. Location of proposed sampling locations in the Lees Mills/Greens Basin region of Lake Winnipesaukee.

Lee's Mills / Green's Basin Area

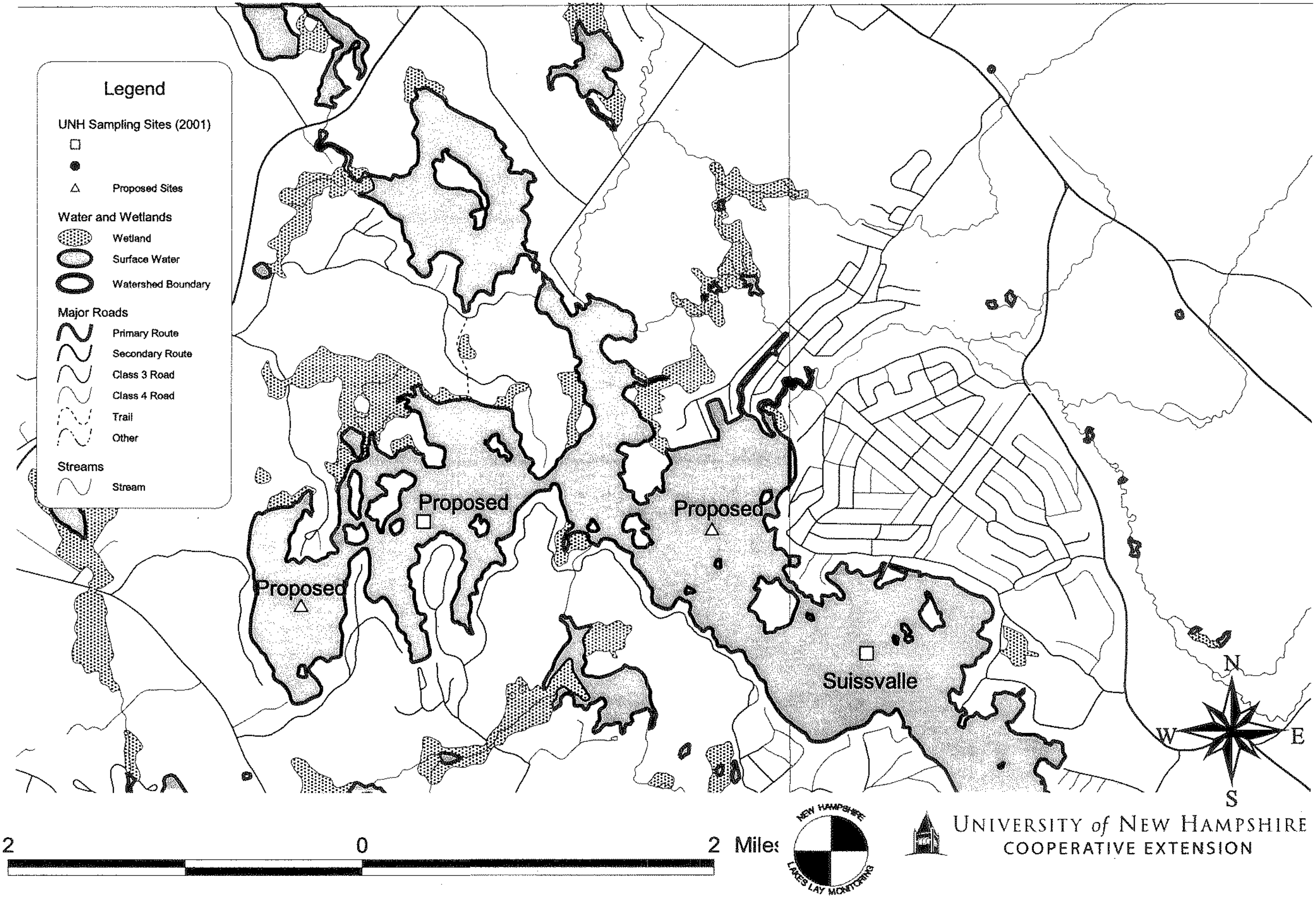
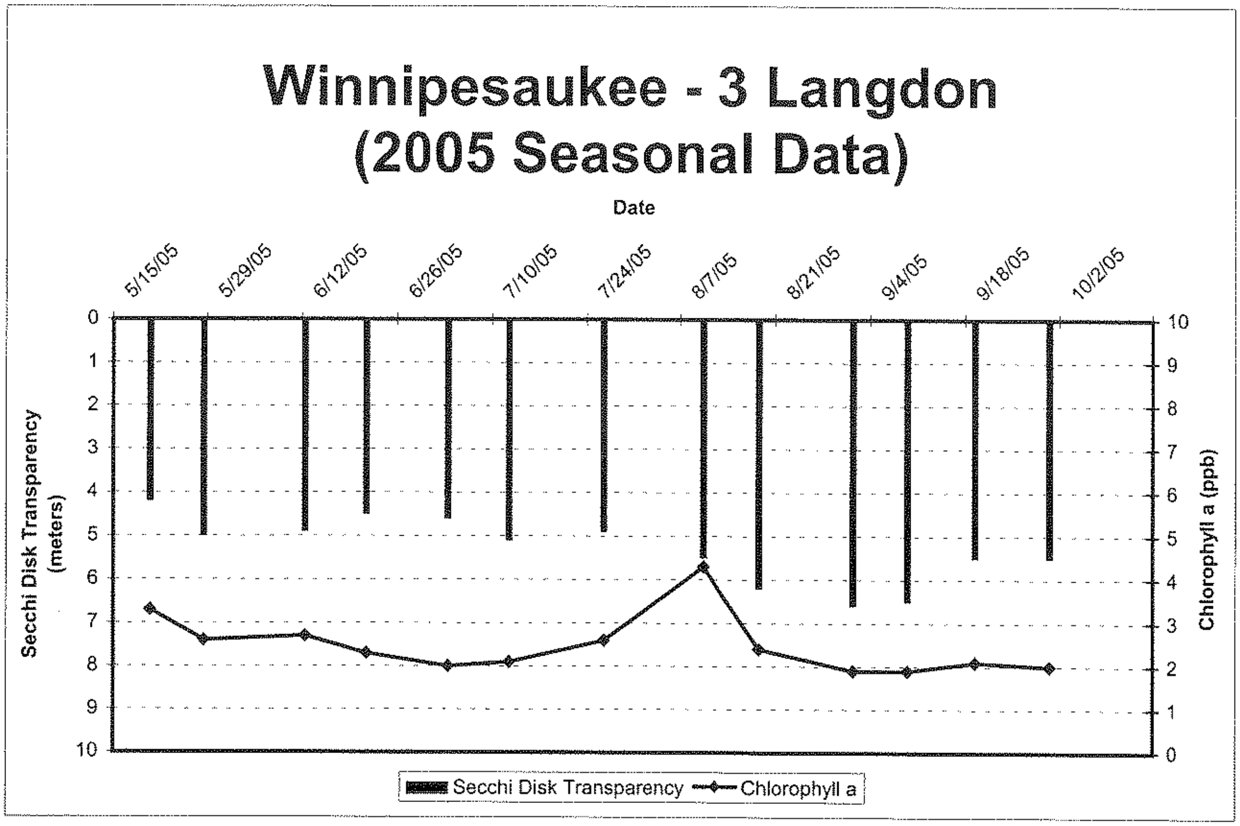
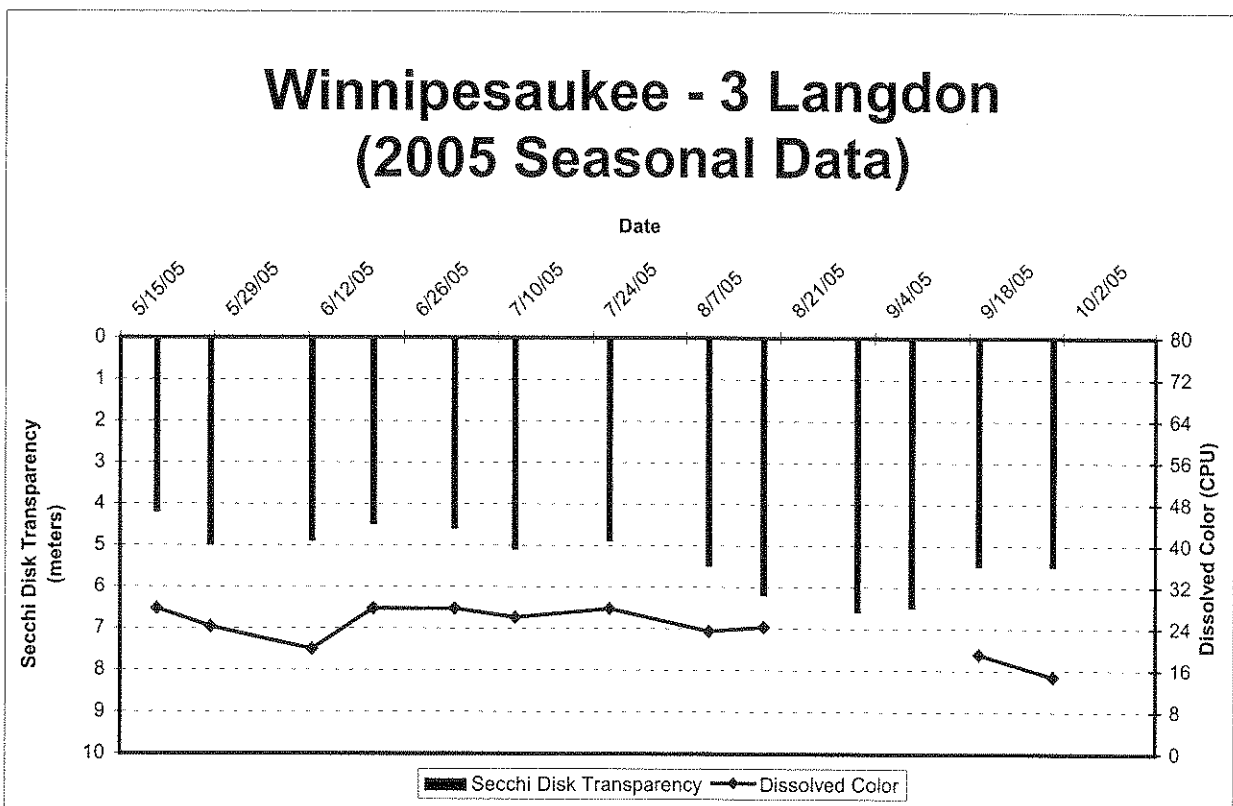


Figure 13. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 3 Langdon Cove. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 14. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 3 Langdon Cove. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - 3 Langdon
(2005 Seasonal Data)
Date
5/15/05
5/29/05
6/12/05
6/26/05
7/10/05
7/24/05
8/7/05
8/21/05
9/4/05
9/18/05
10/2/05
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a


Winnipesaukee - 3 Langdon
(2005 Seasonal Data)
Date
5/15/05
5/29/05
6/12/05
6/26/05
7/10/05
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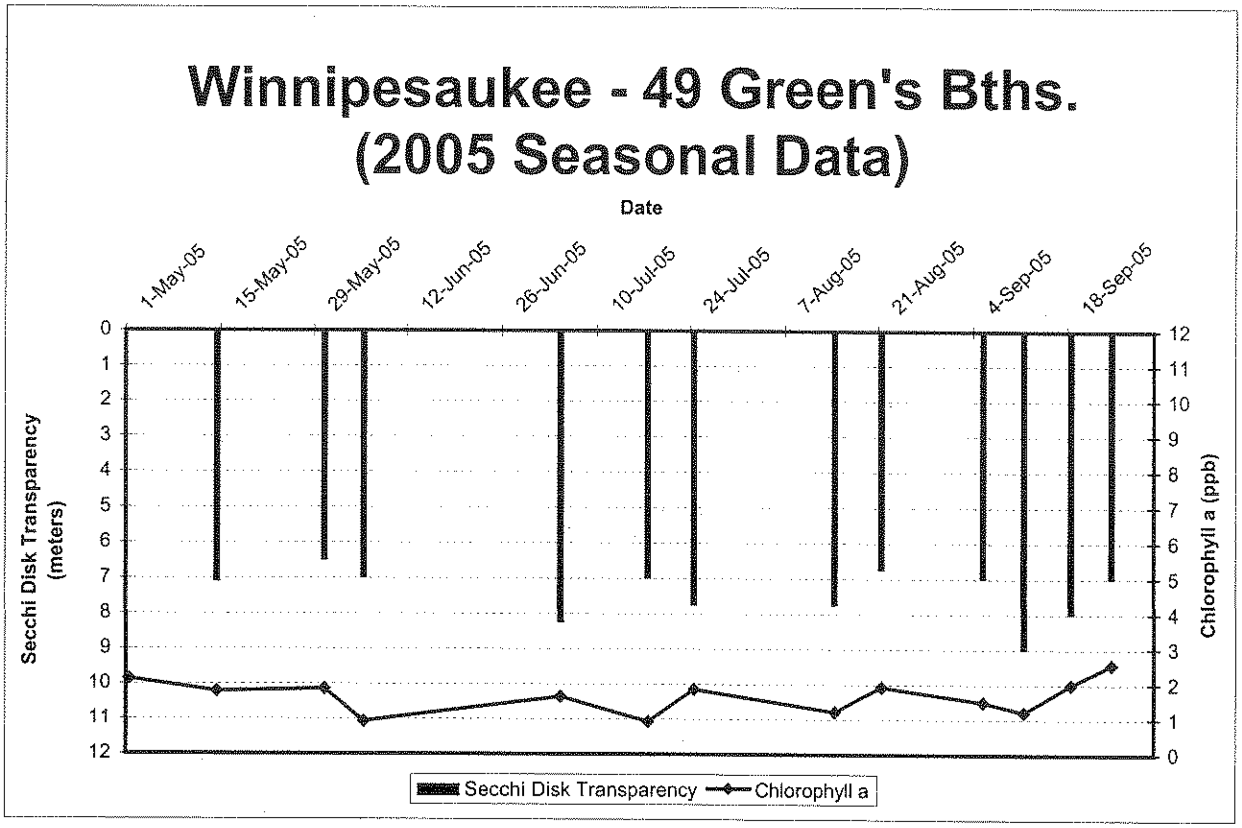
8/7/05
8/21/05
9/4/05
9/18/05
10/2/05
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

Figure 15. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 49 Greens Boathouse. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 16. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 49 Greens Boathouse. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - 49 Green's Bths.
(2005 Seasonal Data)
Date
1-May-05
15-May-05
29-May-05
12-Jun-05
26-Jun-05
10-Jul-05
24-Jul-05
7-Aug-05
21-Aug-05
4-Sep-05
18-Sep-05
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a

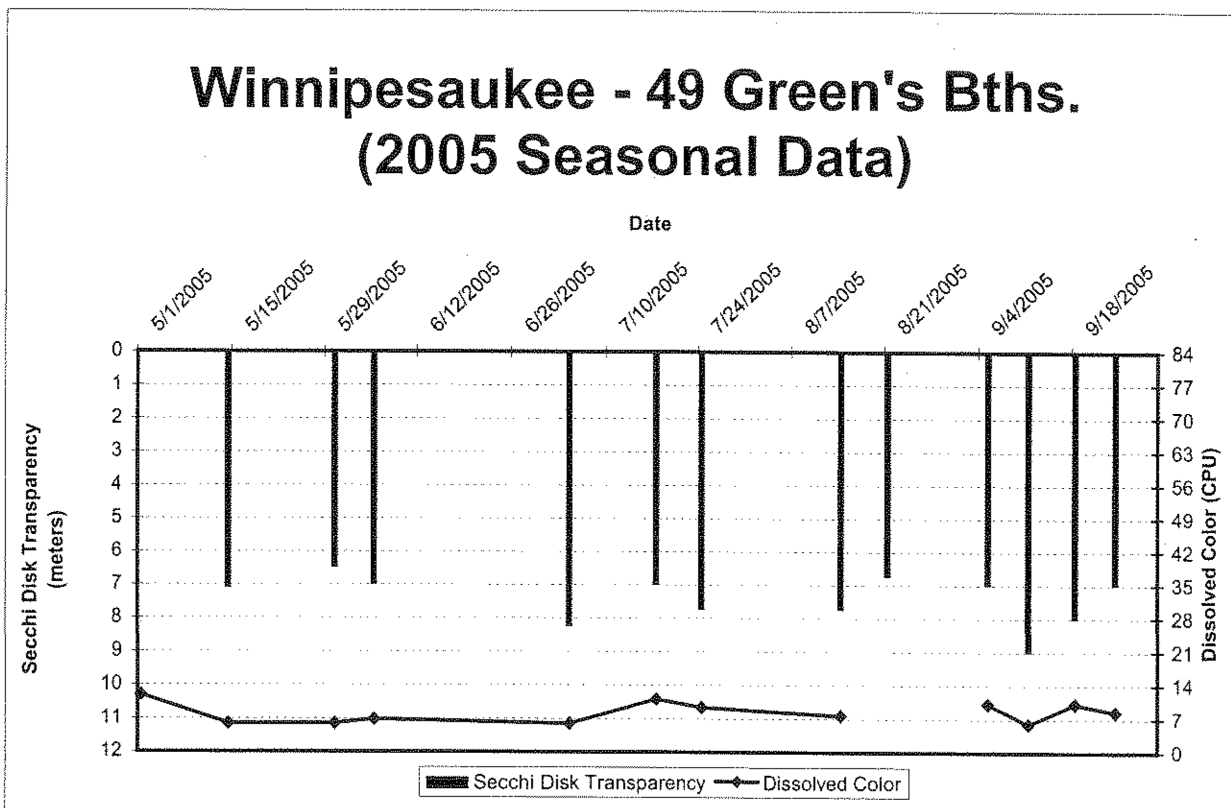
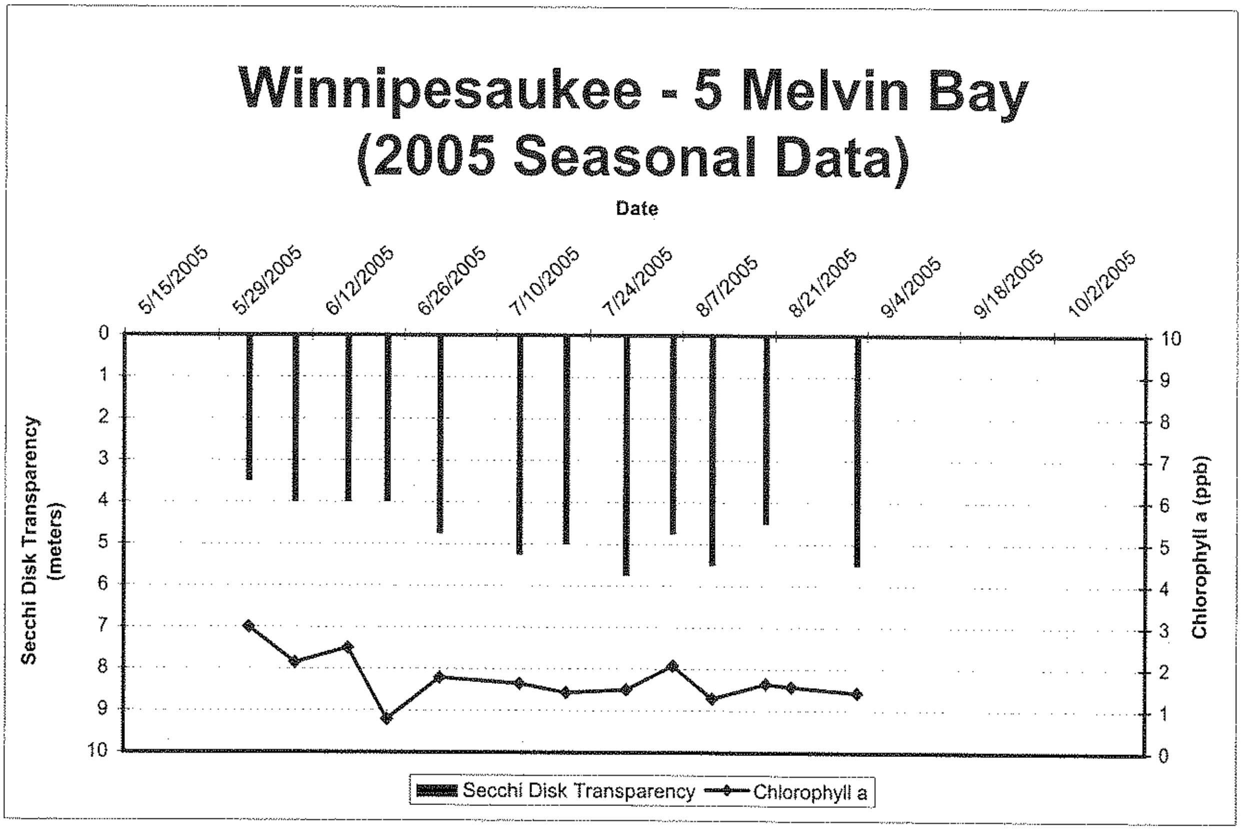

Winnipesaukee - 49 Green's Bths.
(2005 Seasonal Data)
Date
5/1/2005
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

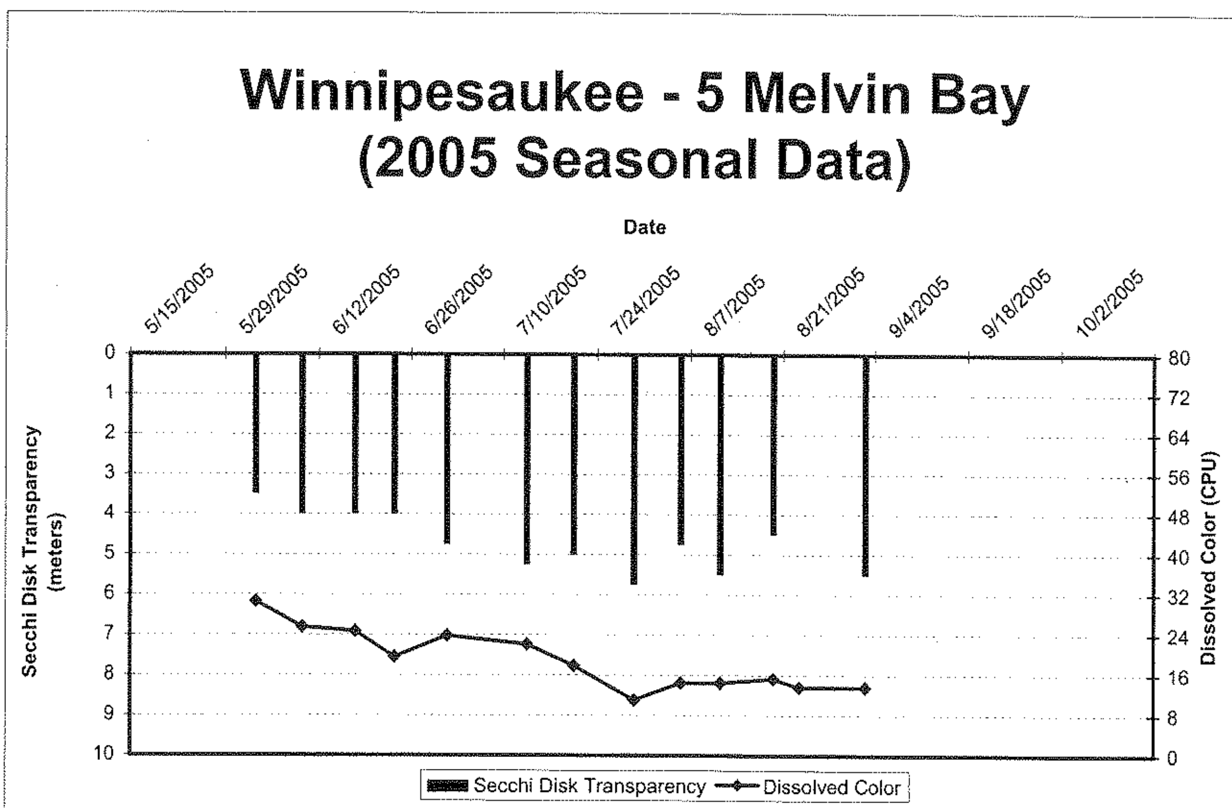
Figure 17. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 5 Melvin Bay. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 18. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 5 Melvin Bay. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).



Winnipesaukee - 5 Melvin Bay
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a

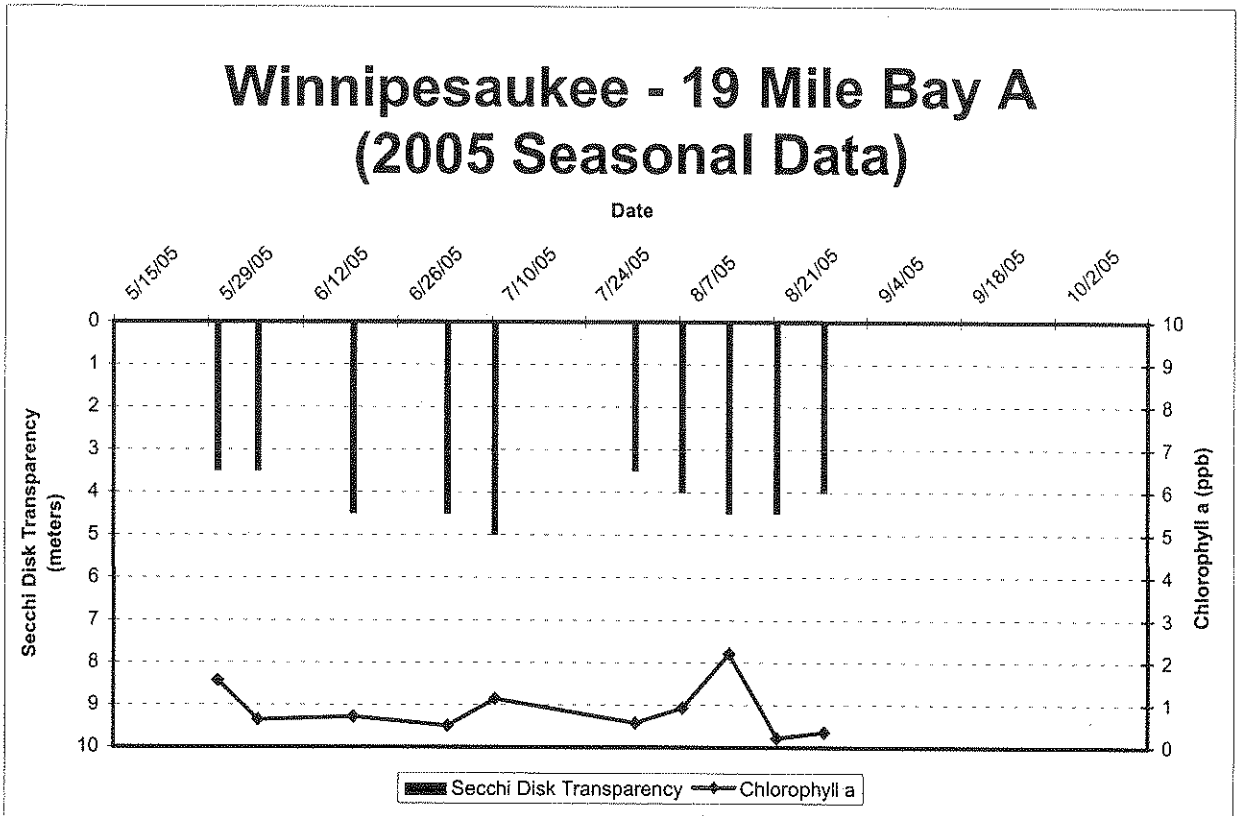


Winnipesaukee - 5 Melvin Bay
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

Figure 19. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 19 Mile Bay (A). The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 20. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 19 Mile Bay (A). The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - 19 Mile Bay A
(2005 Seasonal Data)
Date
5/15/05
5/29/05
6/12/05
6/26/05
7/10/05
7/24/05
8/7/05
8/21/05
9/4/05
9/18/05
10/2/05
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
0
1
2
3
4
5
6
7
8
9
10
Secchi Disk Transparency
Chlorophyll a

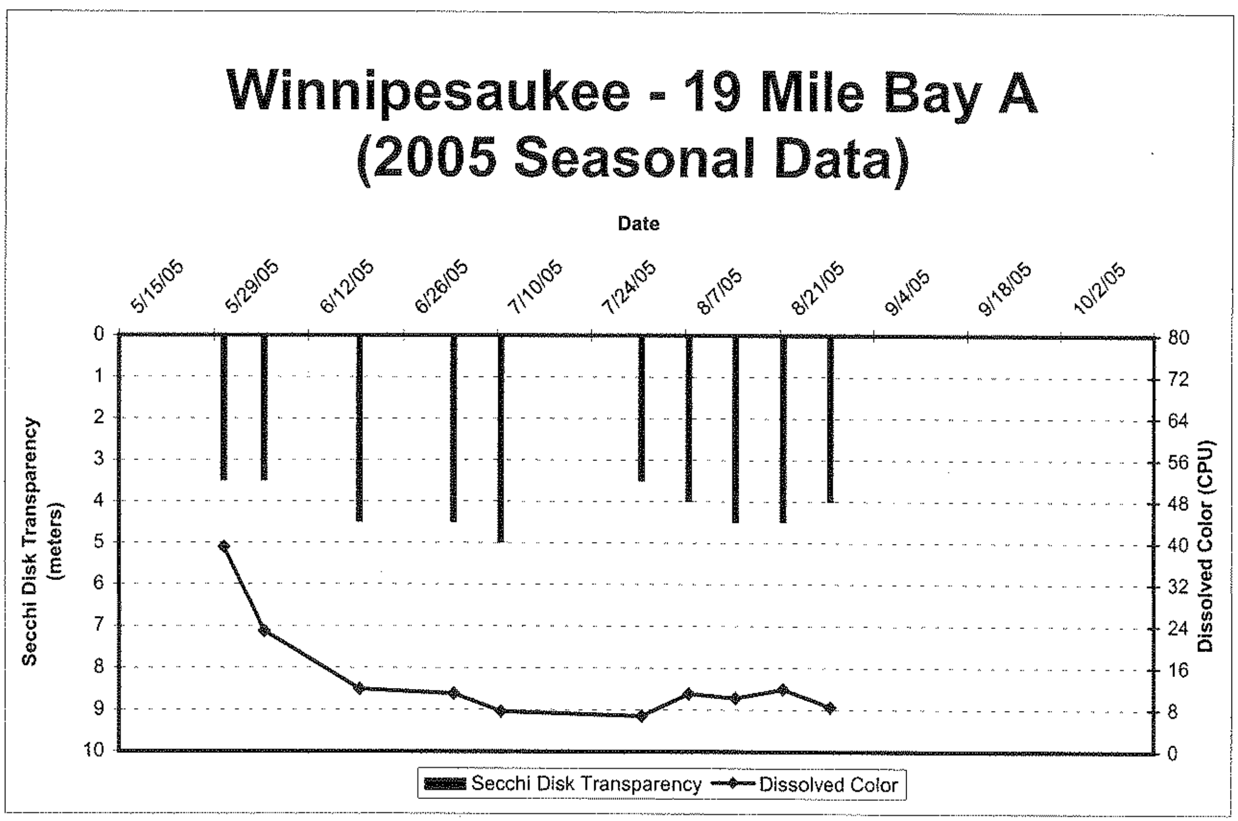
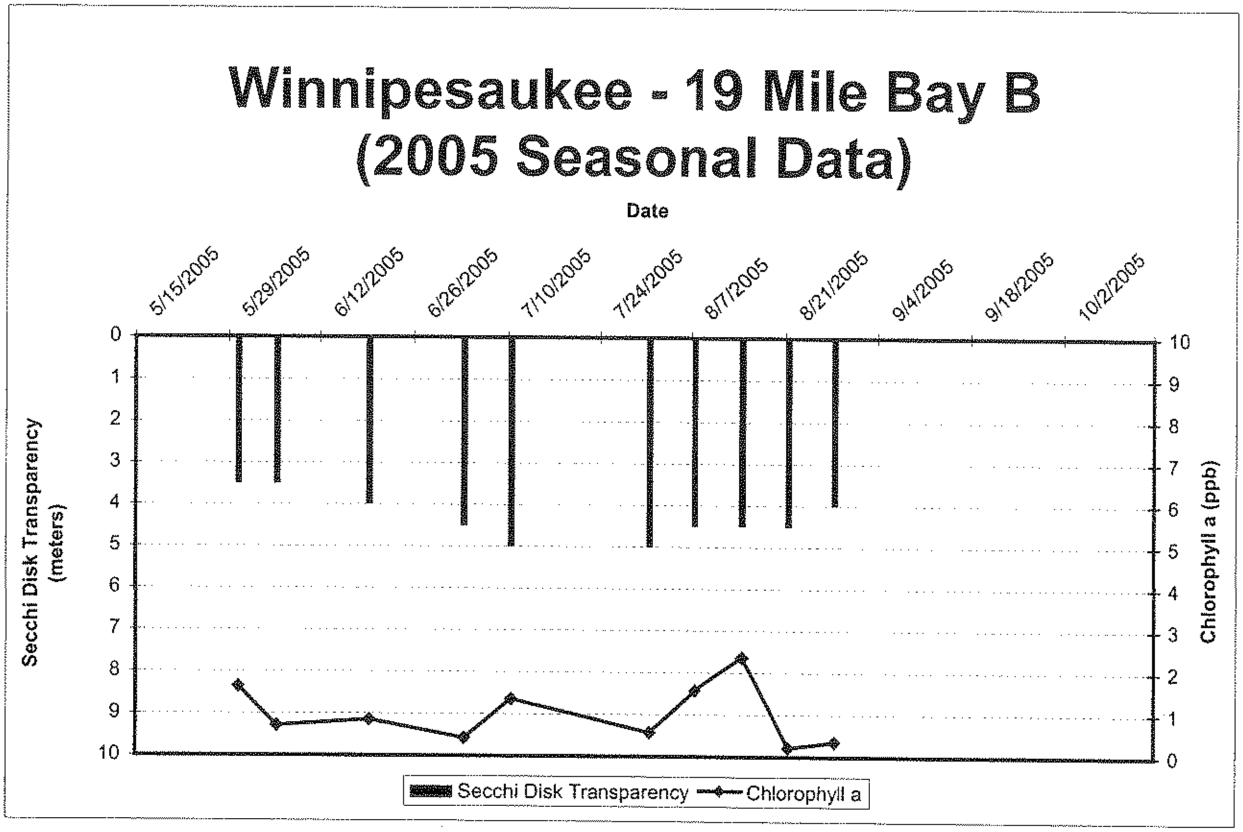

Winnipesaukee - 19 Mile Bay A
(2005 Seasonal Data)
Date
5/15/05
5/29/05
6/12/05
6/26/05
7/10/05
7/24/05
8/7/05
8/21/05
9/4/05
9/18/05
10/2/05
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
0
1
2
3
4
5
6
7
8
9
10
80
72
64
56
48
40
32
24
16
8
Secchi Disk Transparency
Dissolved Color

Figure 21. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 19 Mile Bay (B). The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 22. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 19 Mile Bay (B). The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - 19 Mile Bay B
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a

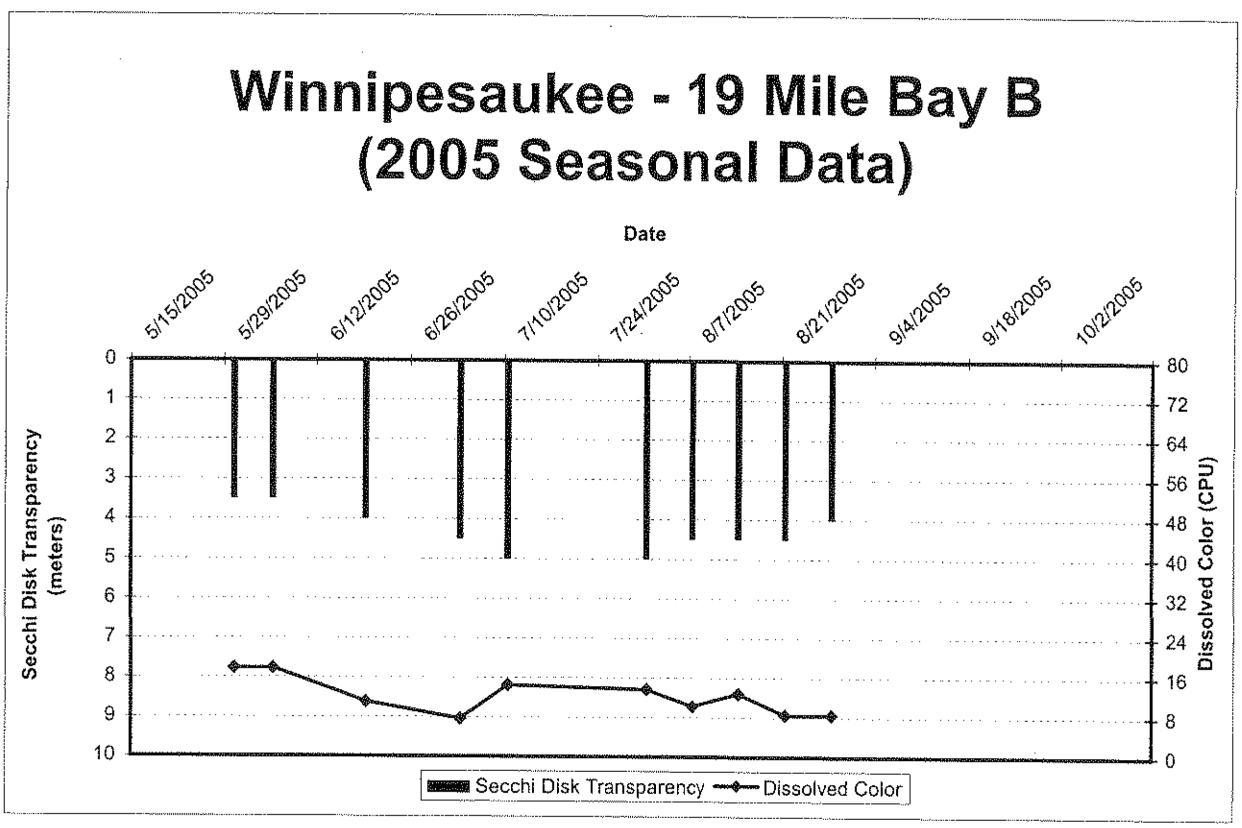
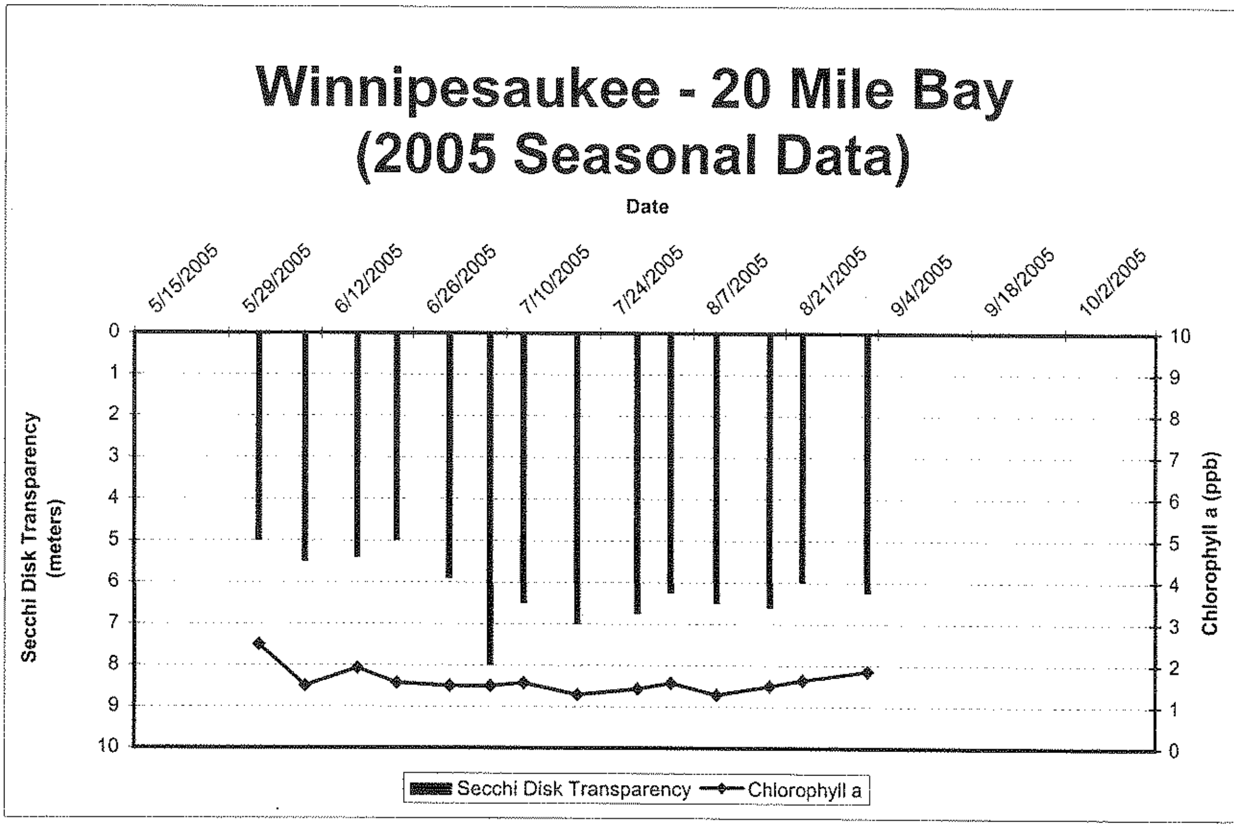

Winnipesaukee - 19 Mile Bay B
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

Figure 23. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site 20 Mile Bay. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 24. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site 20 Mile Bay. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - 20 Mile Bay
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a

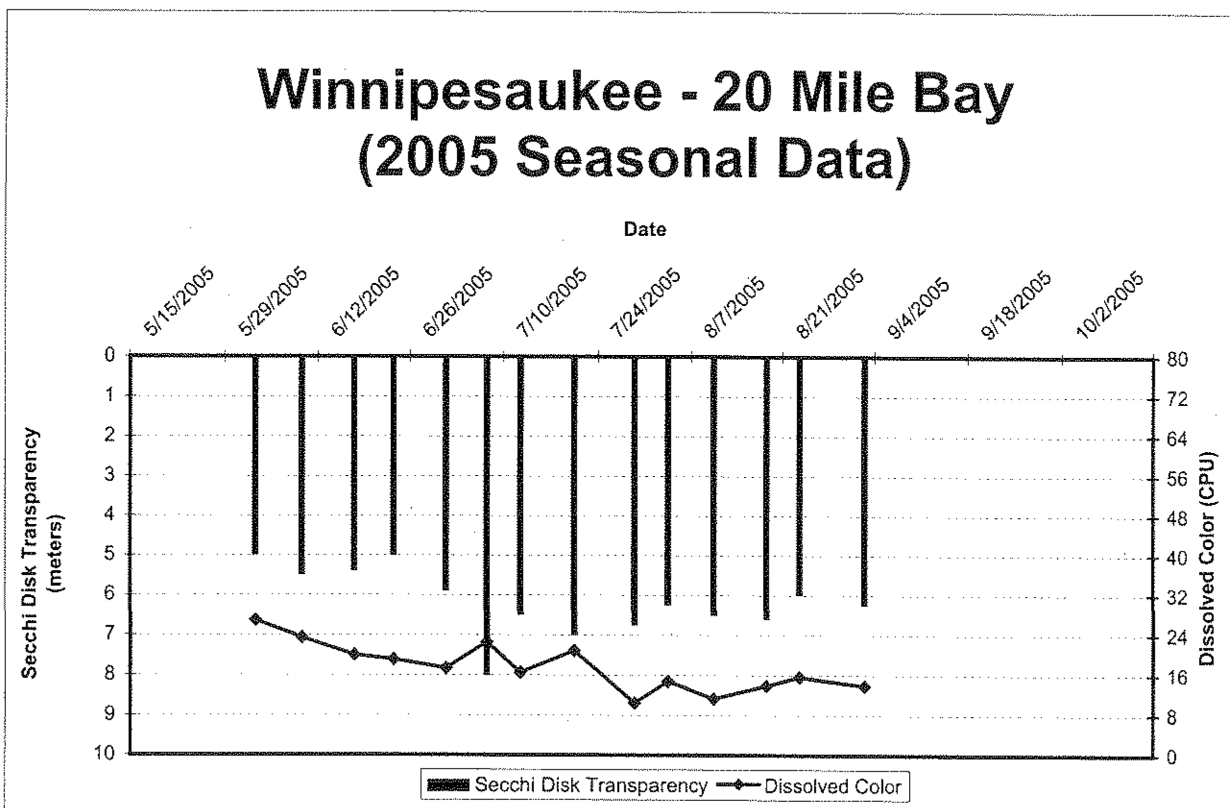
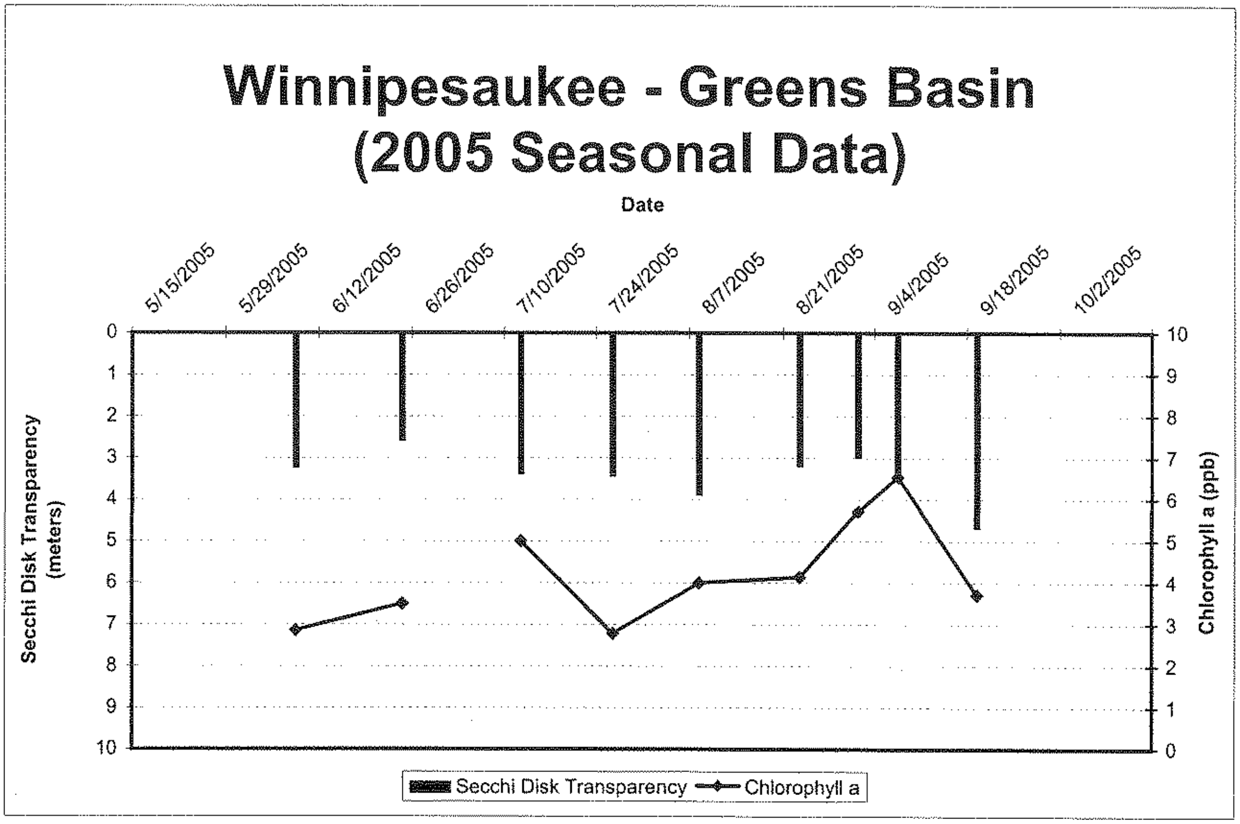
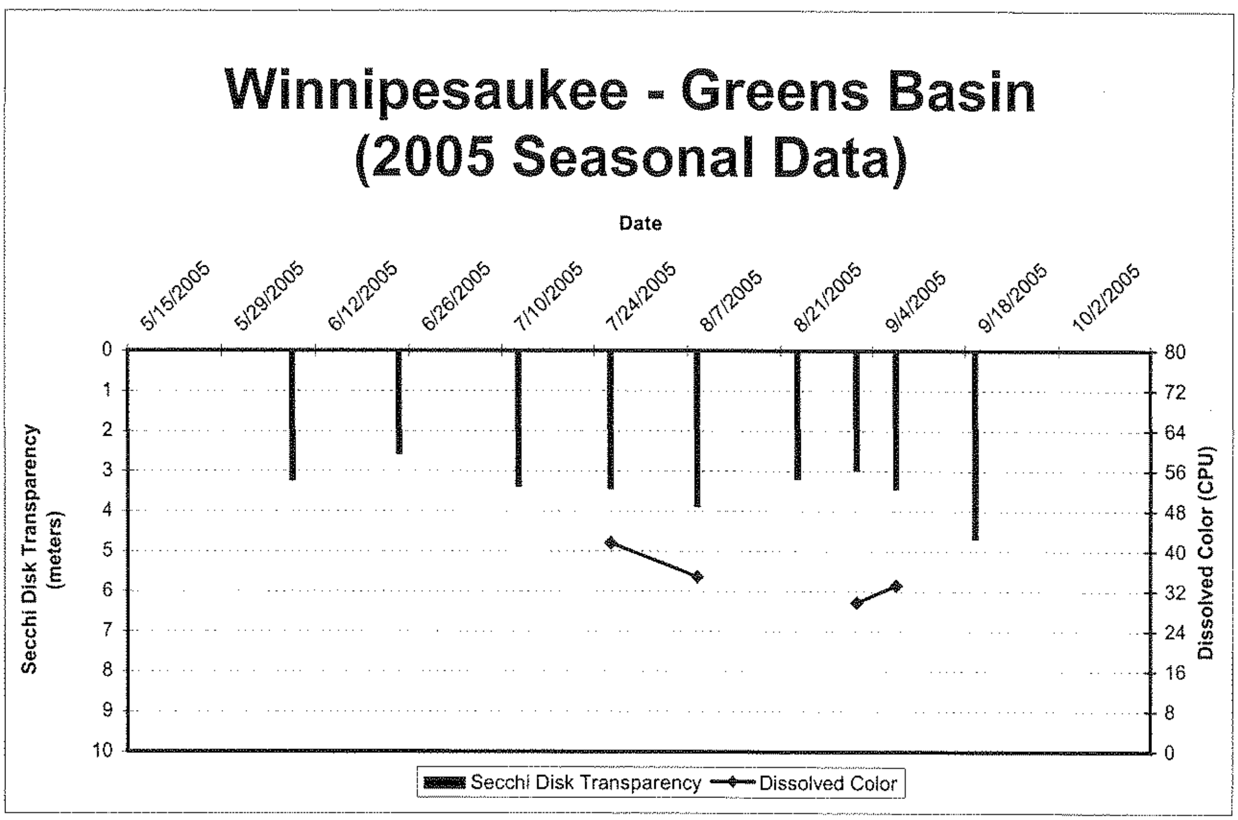

Winnipesaukee - 20 Mile Bay
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

Figure 25. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and chlorophyll *a* trends for Site Greens Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the chlorophyll *a* data are reported to the nearest 0.1 parts per billion (ppb).

Figure 26. Lake Winnipesaukee, 2005. Seasonal Secchi Disk (water transparency) and dissolved color trends for Site Greens Basin. The Secchi Disk transparency data are reported to the nearest 0.1 meters while the dissolved color data are reported to the nearest 0.1 chloroplatinate unit (CPU).

Note: the overlay of the Secchi Disk data with chlorophyll *a* and dissolved color data is intended to provide a visual depiction of the impacts of chlorophyll *a* and dissolved color on water transparency measurements (e.g. higher chlorophyll a and dissolved color concentrations often correspond to shallower water transparencies).


Winnipesaukee - Greens Basin
(2005 Seasonal Data)
Date
5/15/2005
5/29/2005
6/12/2005
6/26/2005
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Chlorophyll a (ppb)
Secchi Disk Transparency
Chlorophyll a


Winnipesaukee - Greens Basin
(2005 Seasonal Data)
Date
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5/29/2005
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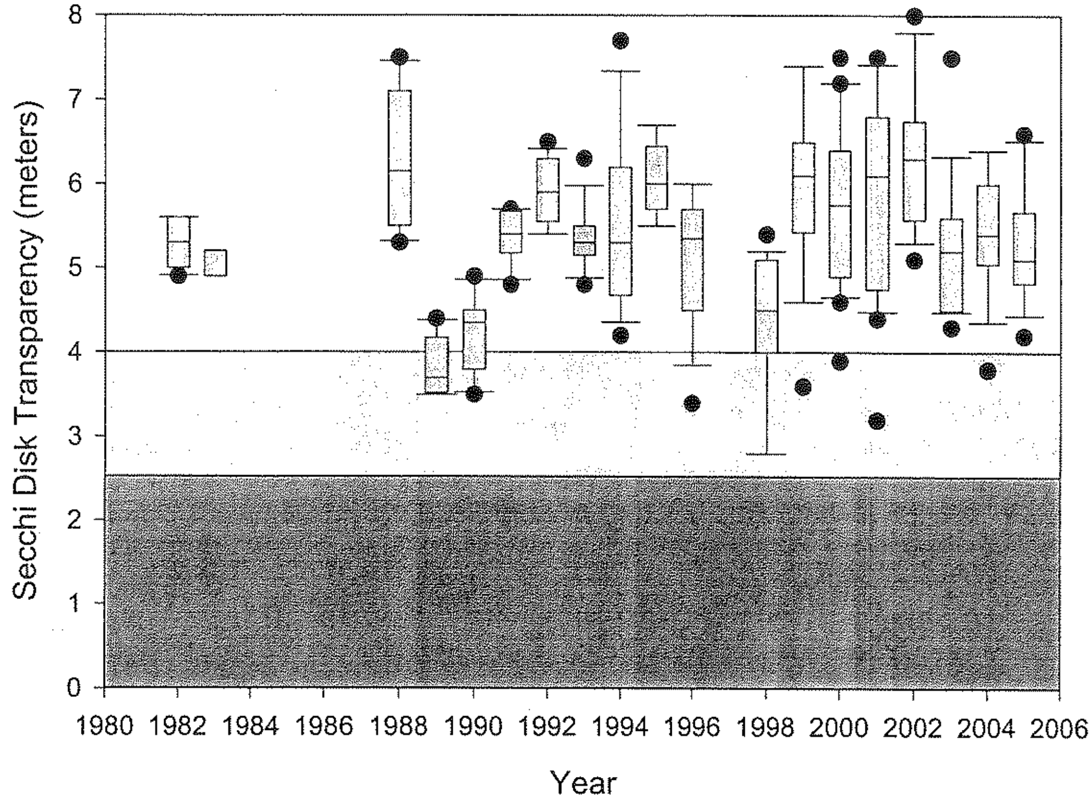
7/10/2005
7/24/2005
8/7/2005
8/21/2005
9/4/2005
9/18/2005
10/2/2005
Secchi Disk Transparency (meters)
Dissolved Color (CPU)
Secchi Disk Transparency
Dissolved Color

Figure 27. Comparison of the annual Winnipesaukee, Site 3 Langdon, lay monitor Secchi Disk transparency data (1982-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 28. Comparison of the annual Winnipesaukee, Site 3 Langdon, lay monitor chlorophyll *a* data (1982-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Winnipesaukee -- Site 3 Langdon
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1982-2005



Winnipesaukee -- Site 3 Langdon
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1982-2005

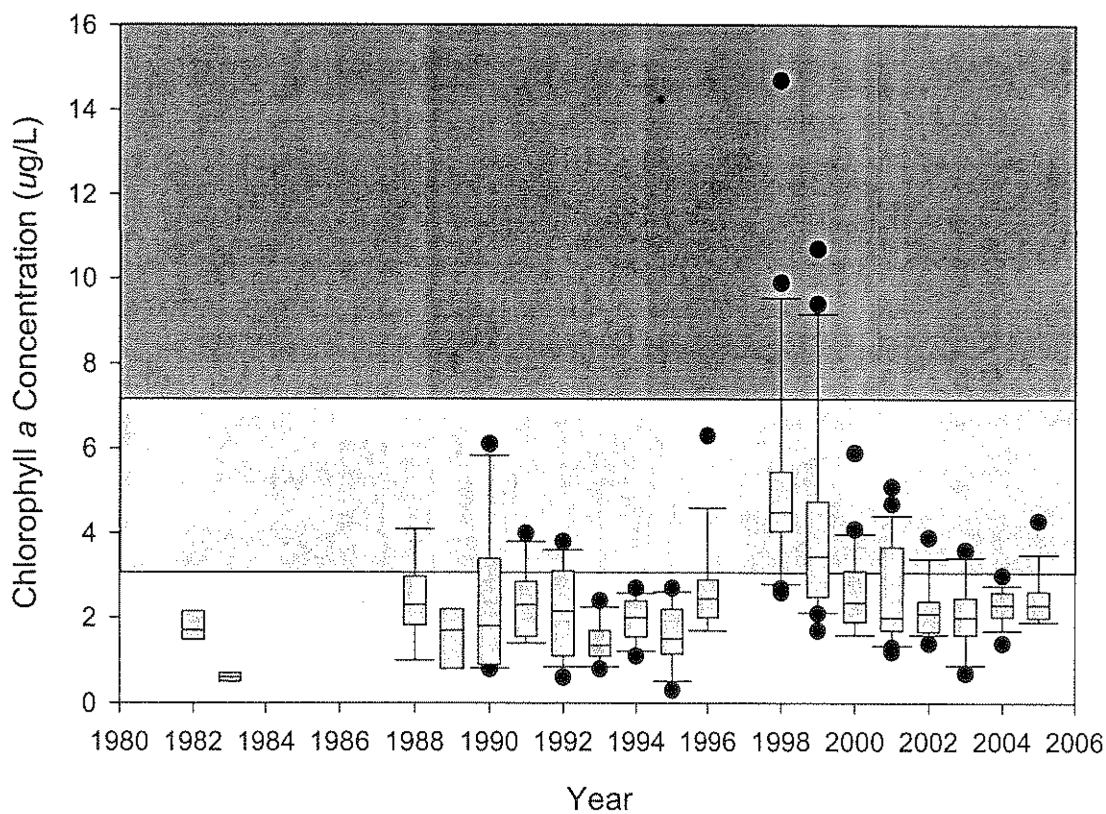
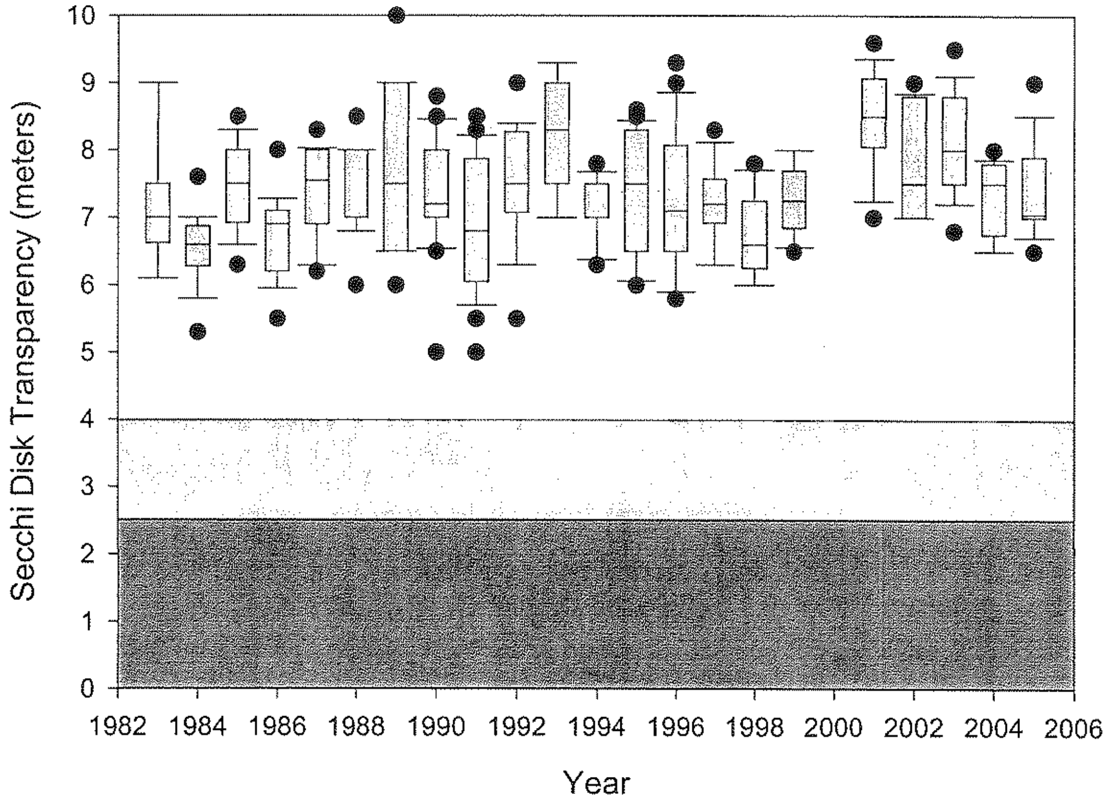


Figure 29. Comparison of the annual Long Island, Site 49 Greens Boathouse, lay monitor Secchi Disk transparency data (1983-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 30. Comparison of the annual Long Island, Site 49 Greens Boathouse, lay monitor chlorophyll *a* data (1983-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Winni-Long Island -- Site 49 Green's Boathouse
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1983-2005



Winni-Long Island -- Site 49 Green's Boathouse
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1983-2005

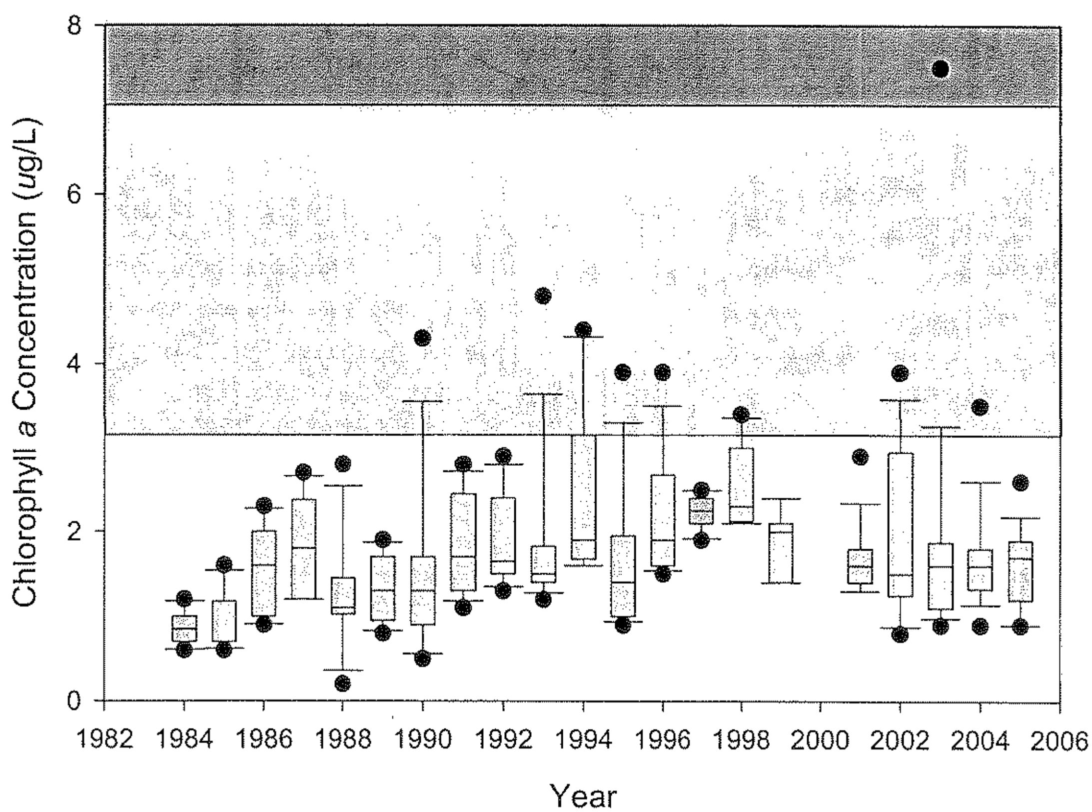
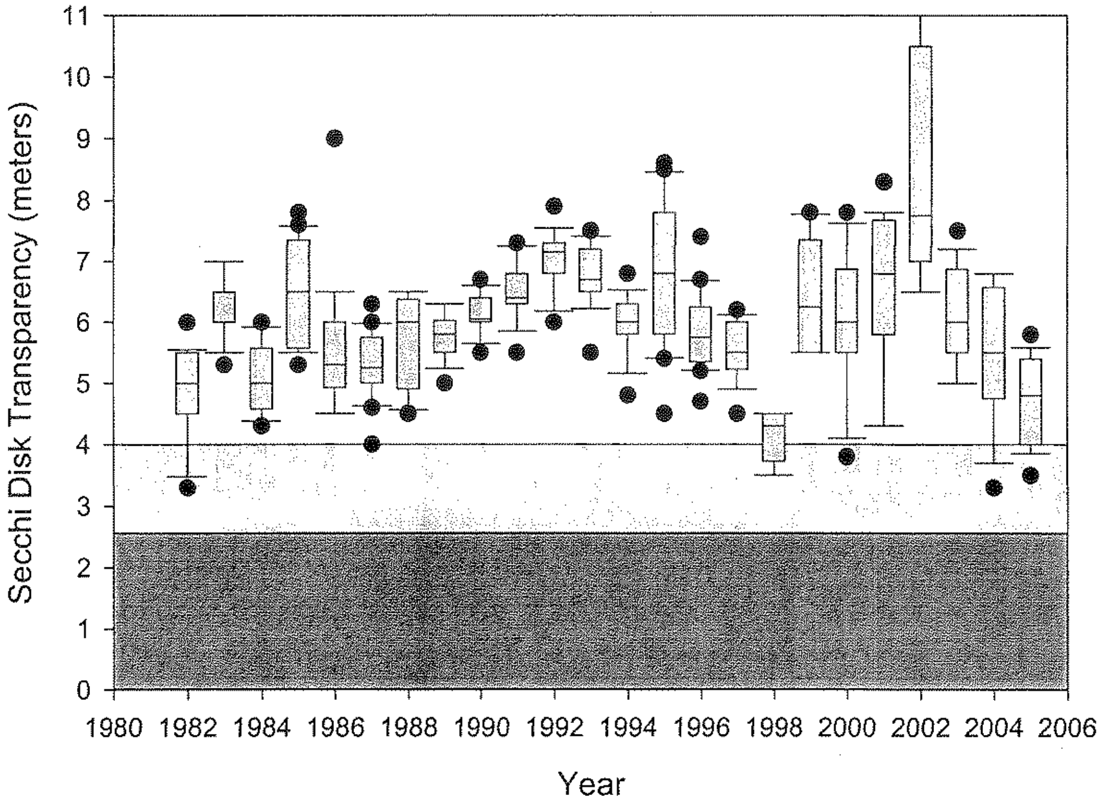


Figure 31. Comparison of the annual Moultonborough Bay, Site 5 Melvin Bay, lay monitor Secchi Disk transparency data (1982-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 32. Comparison of the annual Moultonborough Bay, Site 5 Melvin Bay, lay monitor chlorophyll *a* data (1982-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Winni-Moulton Bay -- Site 5 Melvin
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1982-2005



Winni-Moulton Bay -- Site 5 Melvin
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1982-2005

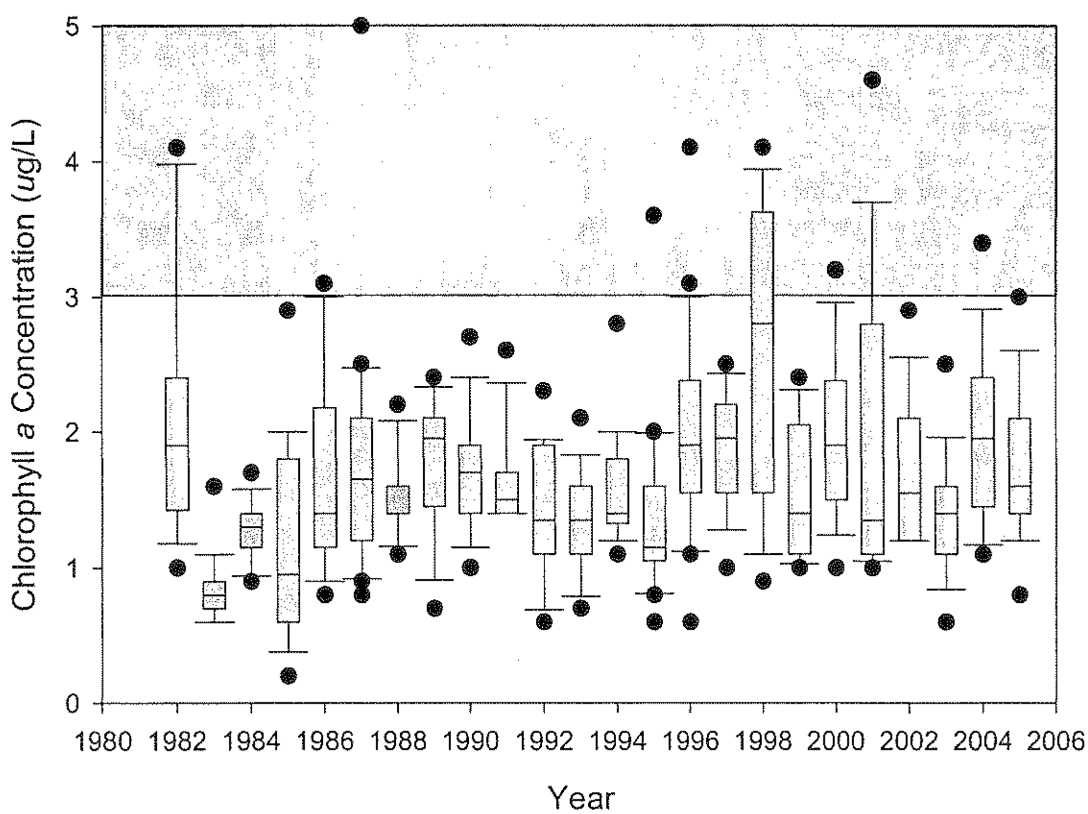
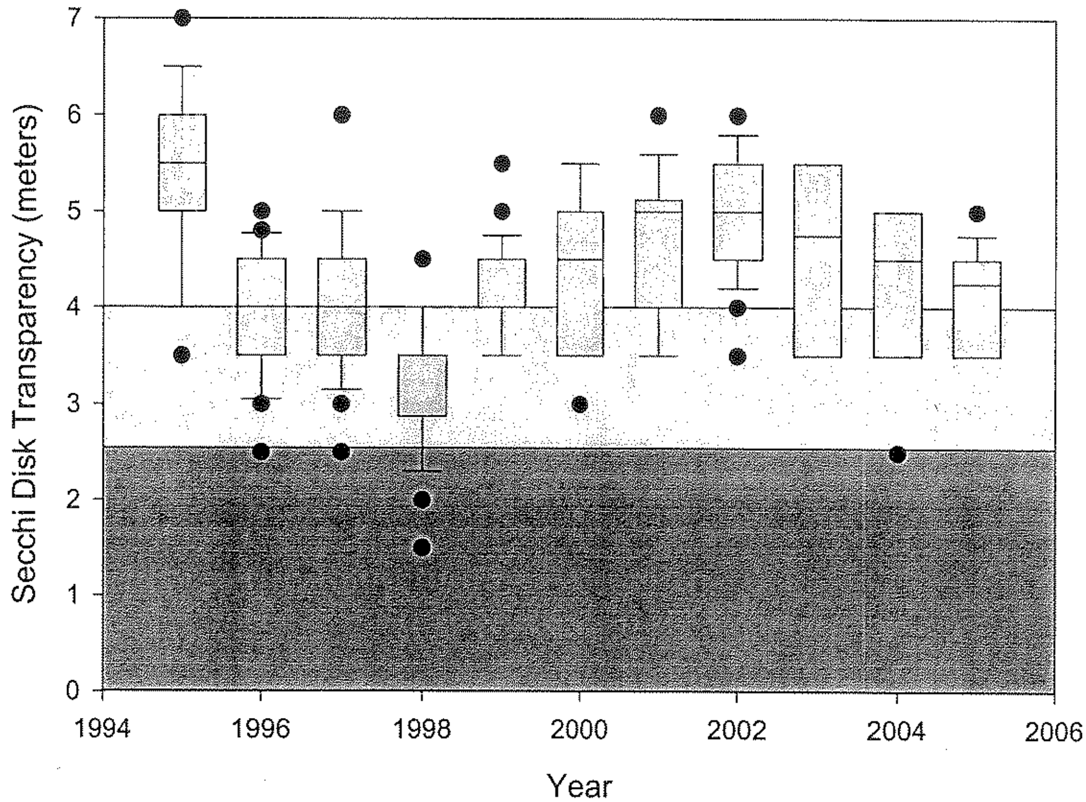


Figure 33. Comparison of the annual Moultonborough Bay, Site 19 Mile Bay (A), lay monitor Secchi Disk transparency data (1995-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 34. Comparison of the annual Moultonborough Bay, Site 19 Mile Bay (A), lay monitor chlorophyll *a* data (1995-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Winni-Moulton Bay -- Site 19 Mlie Bay A
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1995-2005



Winni-Moulton Bay -- Site 19 Mile Bay A
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1995-2005

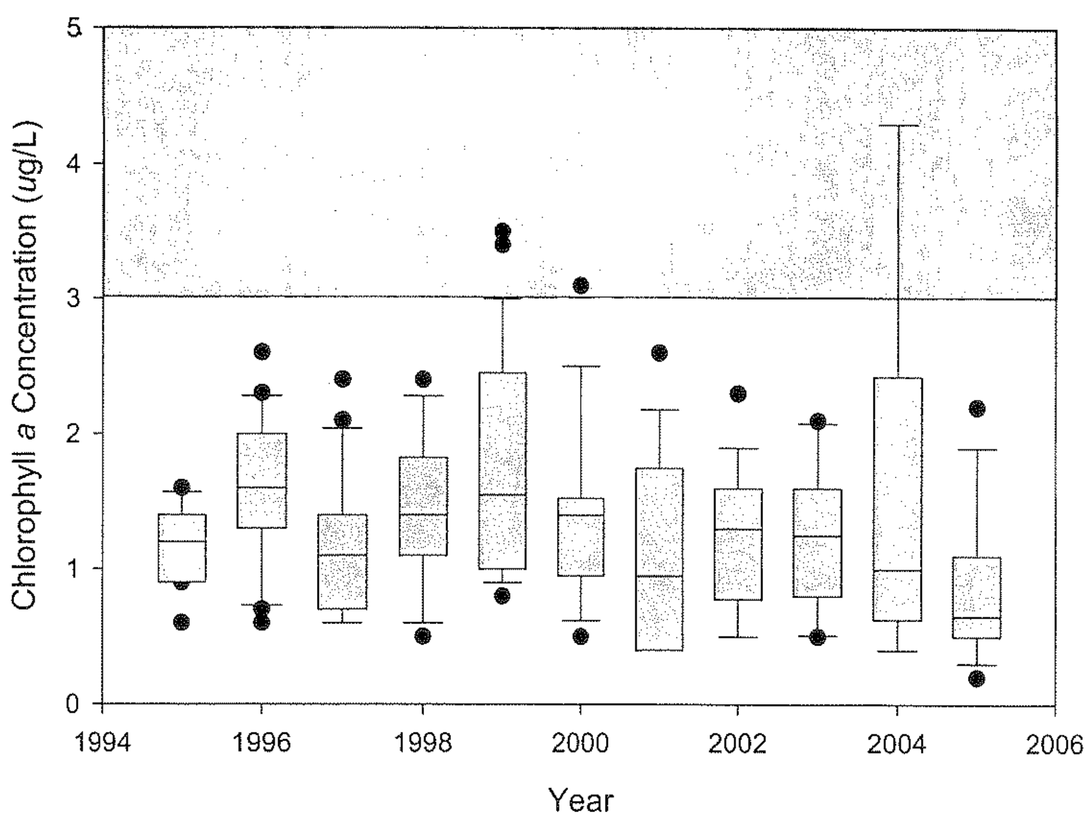
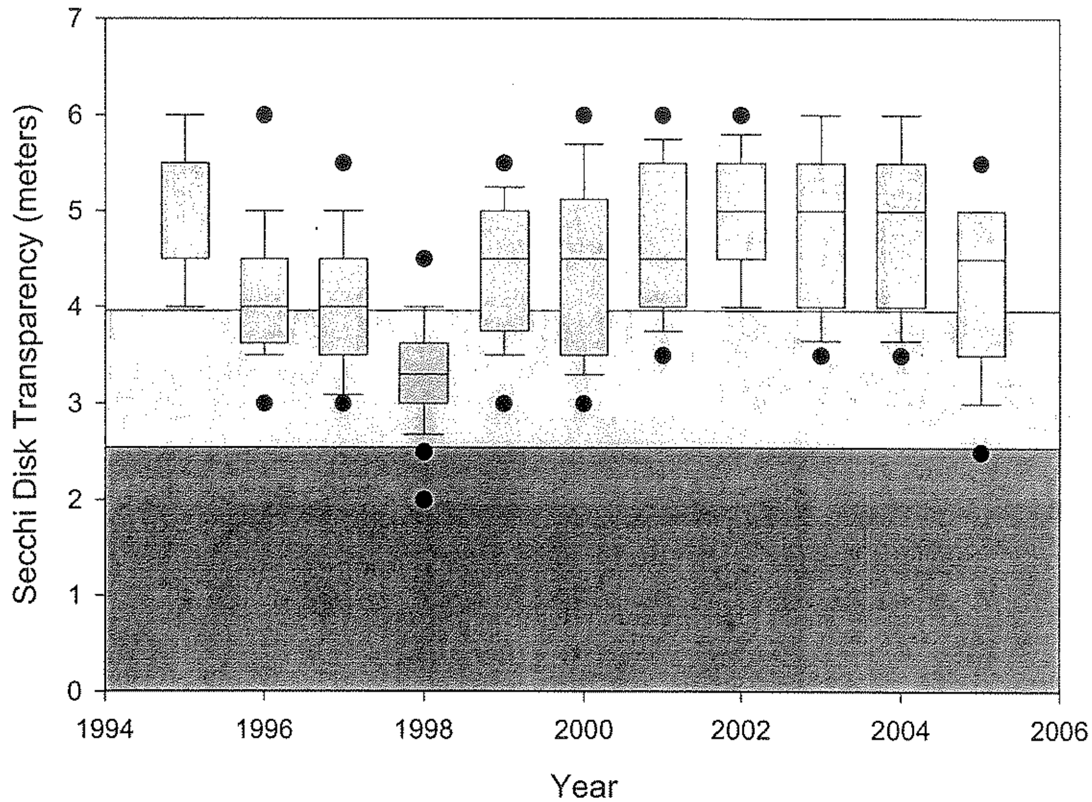


Figure 35. Comparison of the annual Moultonborough Bay, Site 19 Mile Bay (B), lay monitor Secchi Disk transparency data (1995-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 36. Comparison of the annual Moultonborough Bay, Site 19 Mile Bay (B), lay monitor chlorophyll *a* data (1995-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Winni-Moulton Bay -- Site 19 Mile Bay B
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1995-2005



Winni-Moulton Bay -- Site 19 Mile Bay B
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1995-2005

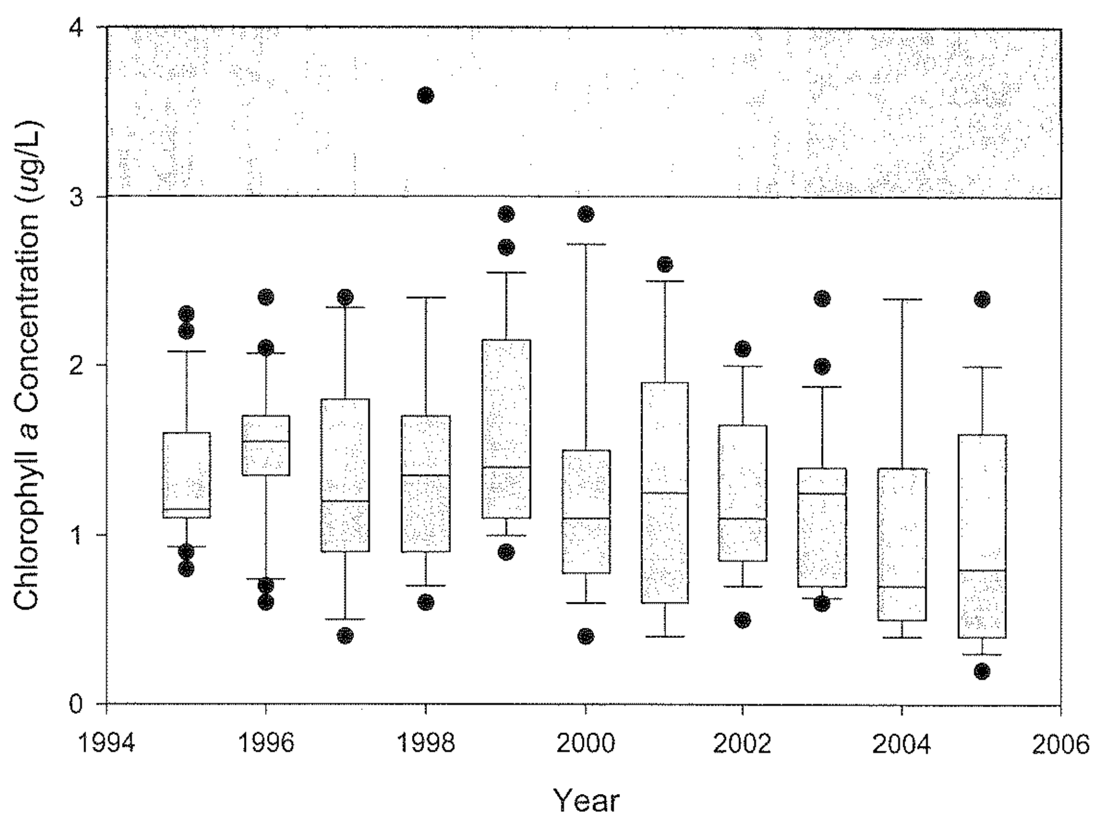
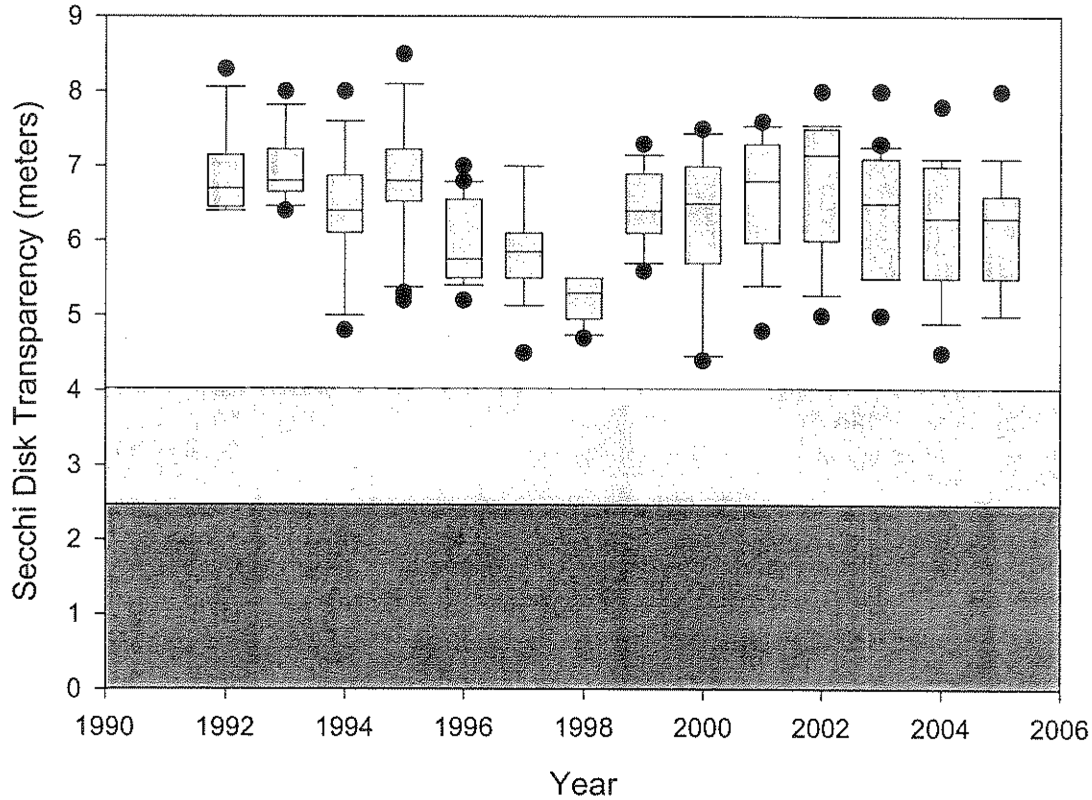


Figure 37. Comparison of the annual Moultonborough Bay, Site 20 Mile Bay, lay monitor Secchi Disk transparency data (1992-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 38. Comparison of the annual Moultonborough Bay, Site 20 Mile Bay, lay monitor chlorophyll *a* data (1992-2005) that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Winni-Moulton Bay -- Site 20 Mile Bay
Annual Secchi Disk Transparency Comparisons
Box and Whisker Plots: 1992-2005



Winni-Moulton Bay -- Site 20 Mile Bay
Annual Chlorophyll *a* Comparisons
Box and Whisker Plots: 1992-2005

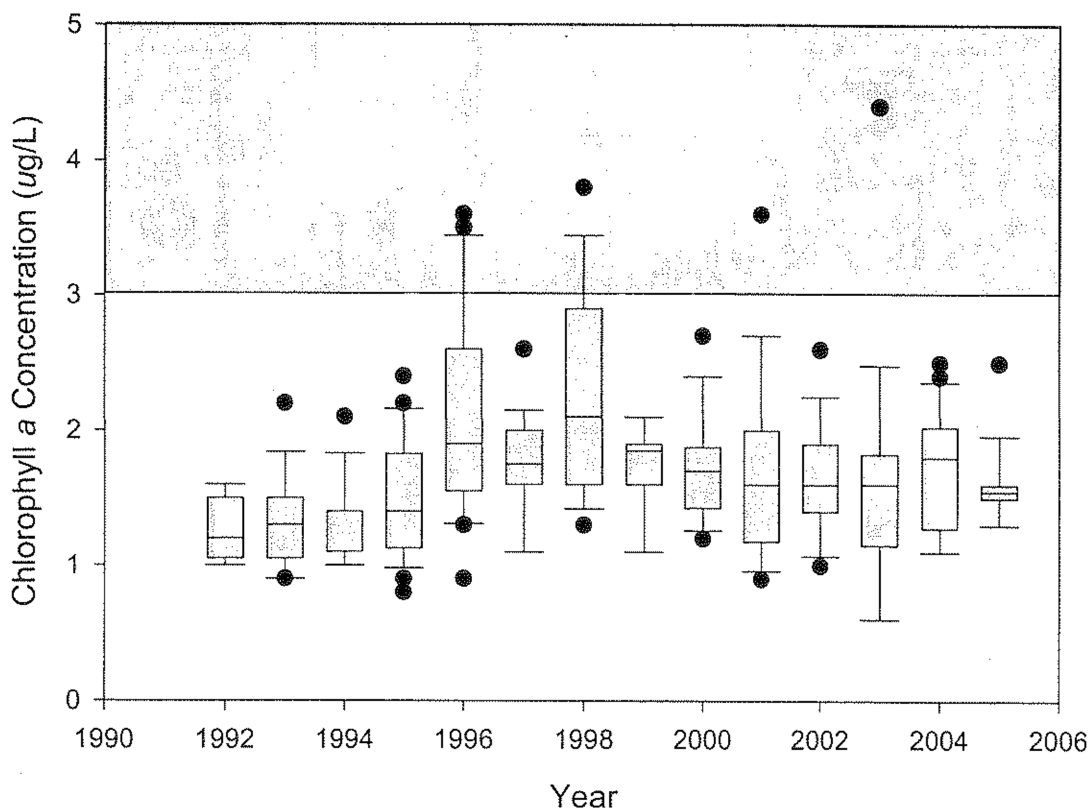
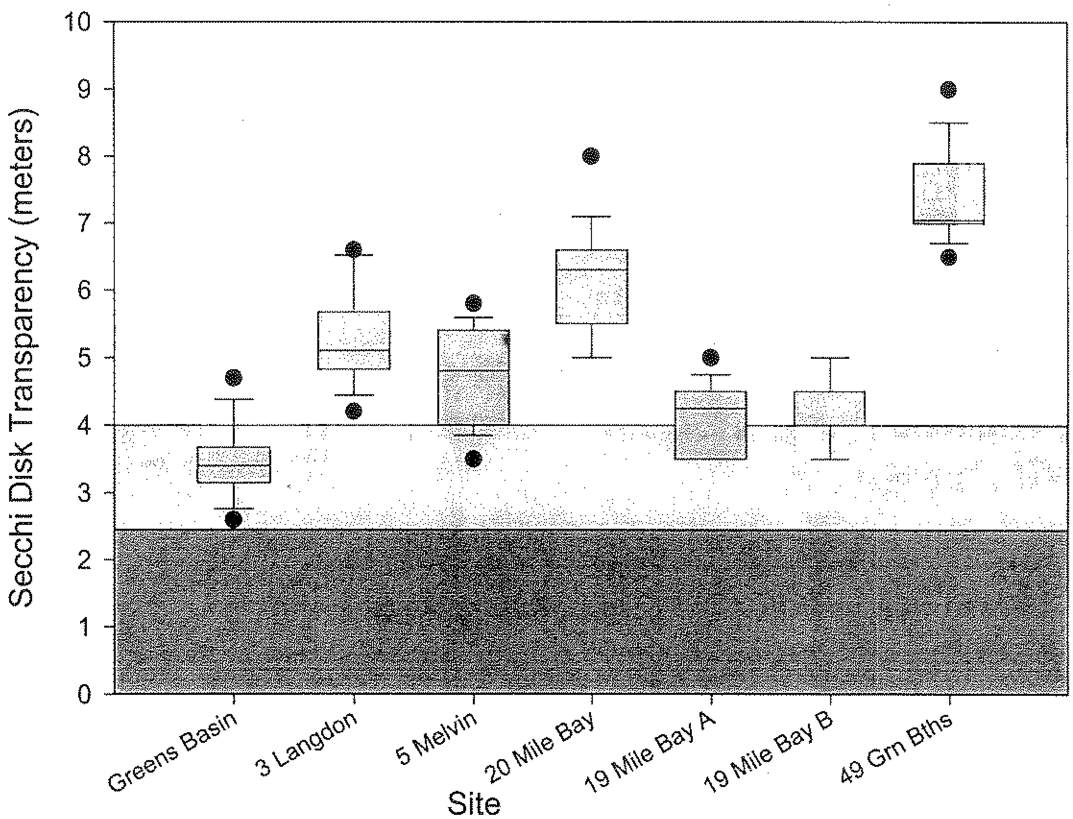


Figure 39. Moultonborough Bay inter-site comparison of the 2005 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 40. Moultonborough Bay inter-site comparison of the 2005 lay monitor Chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Moultonborough Bay -- Inter-Site Comparison
Secchi Disk Transparency Data
Box and Whisker Plots: 2005



Moultonborough Bay -- Inter-Site Comparison
Chlorophyll *a* Data
Box and Whisker Plots: 2005

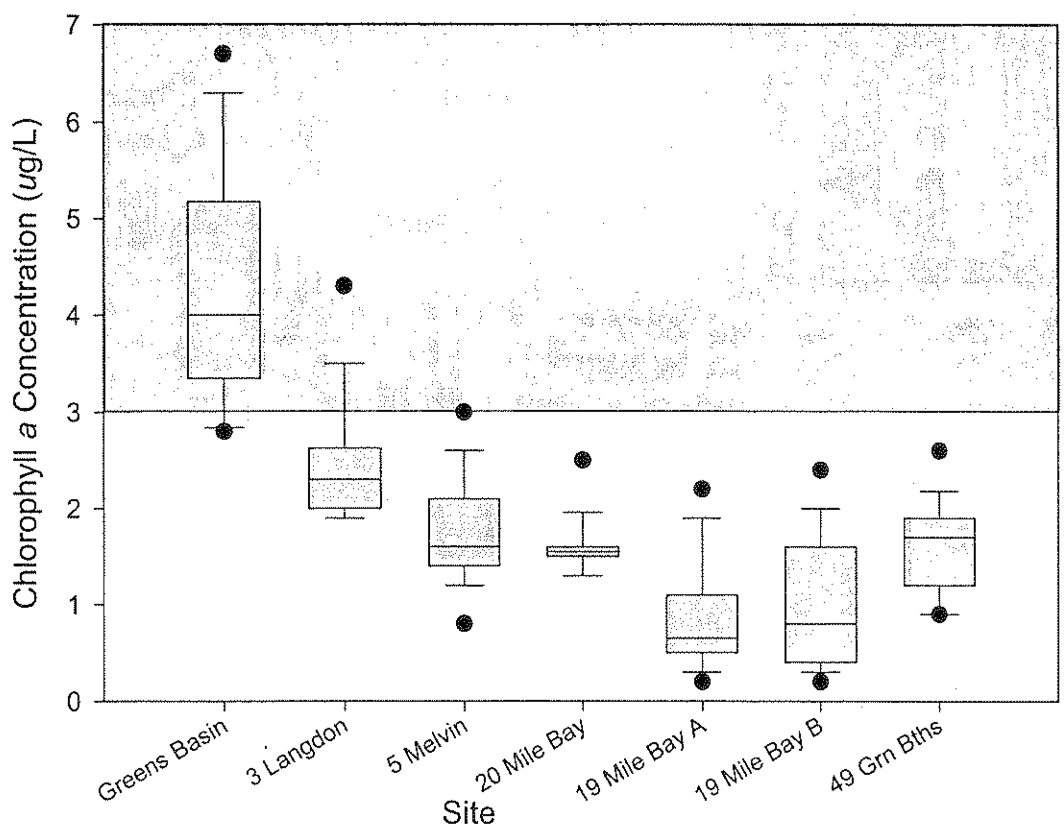
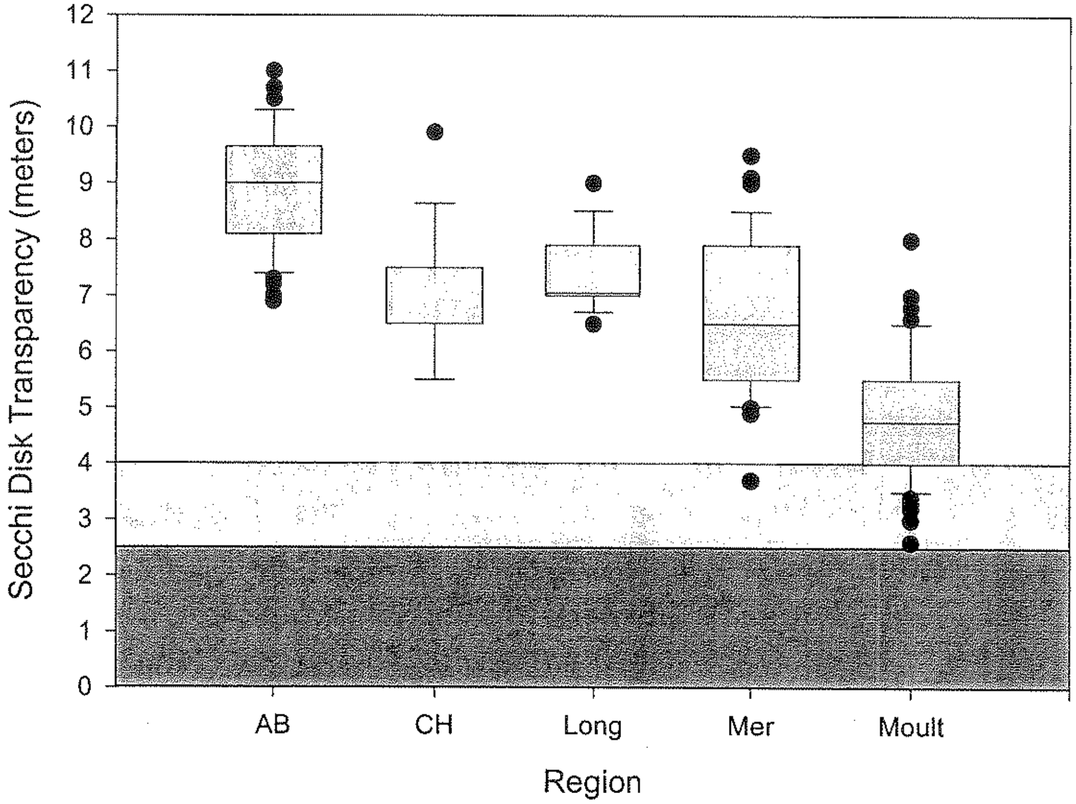


Figure 41. Regional comparison of the 2005 lay monitor Secchi Disk transparency data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded), moderately productive (light gray shading), and highly productive (dark gray shading) lakes.

Figure 42. Regional comparison of the 2005 lay monitor Chlorophyll *a* data that are presented as box and whisker plots. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. The gray shaded areas on the graph denote the ranges characteristic of unproductive (non-shaded) and moderately productive (light gray shading) lakes.

Winnipesaukee -- Regional Comparison
Secchi Disk Transparency Comparisons
Box and Whisker Plots: 2005



Winnipesaukee -- Regional Comparison
Chlorophyll *a* Comparisons
Box and Whisker Plots: 2005

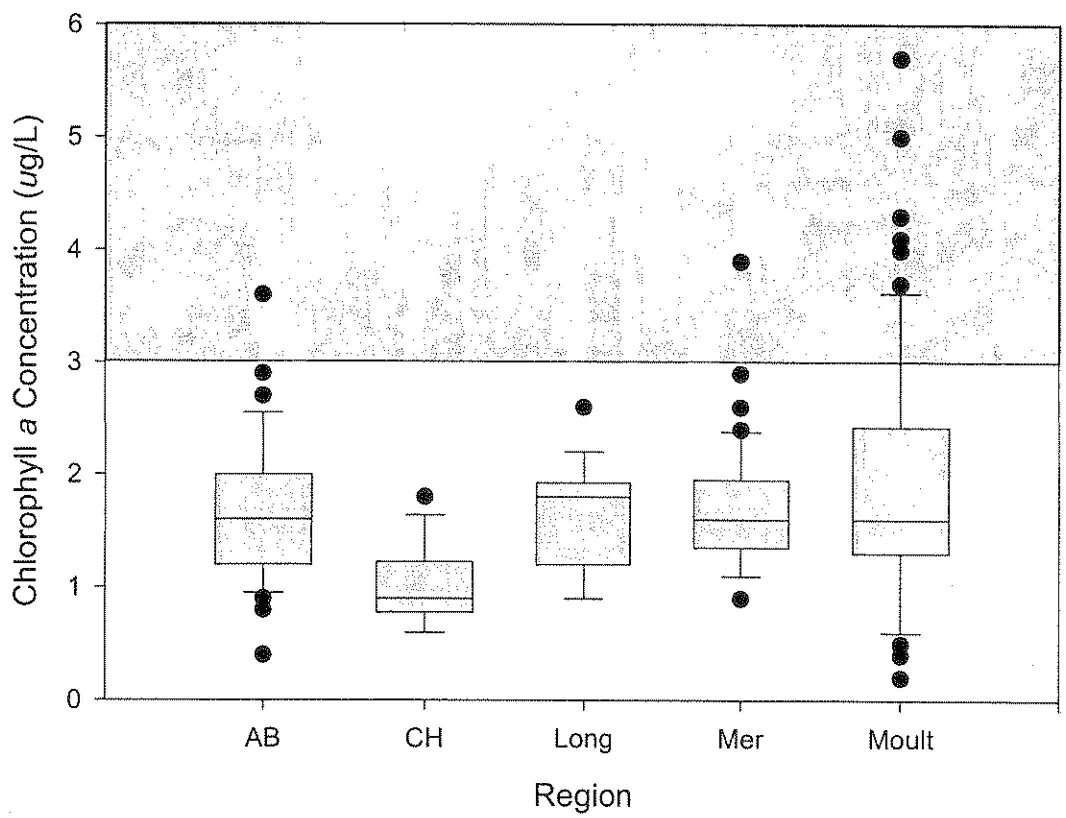
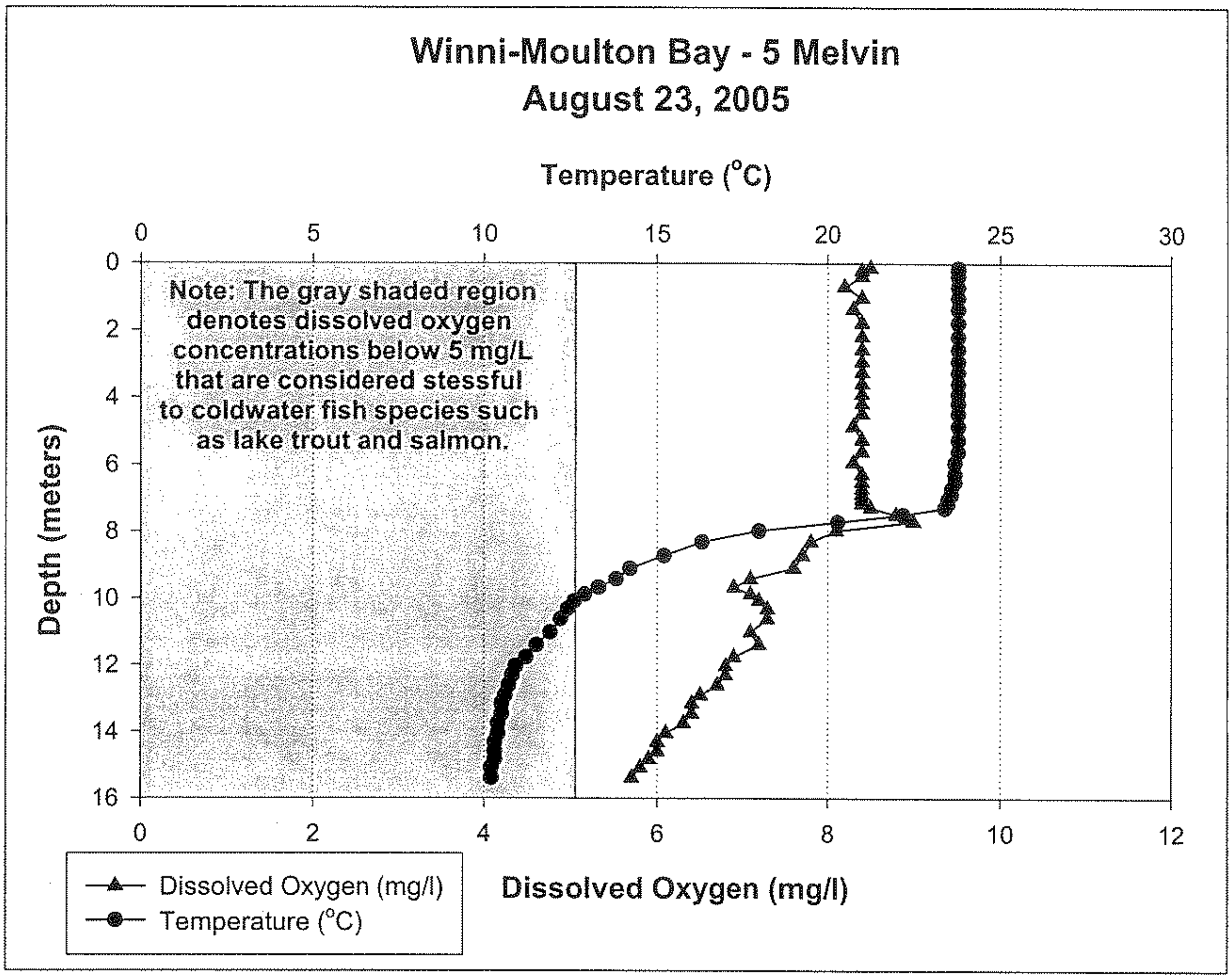
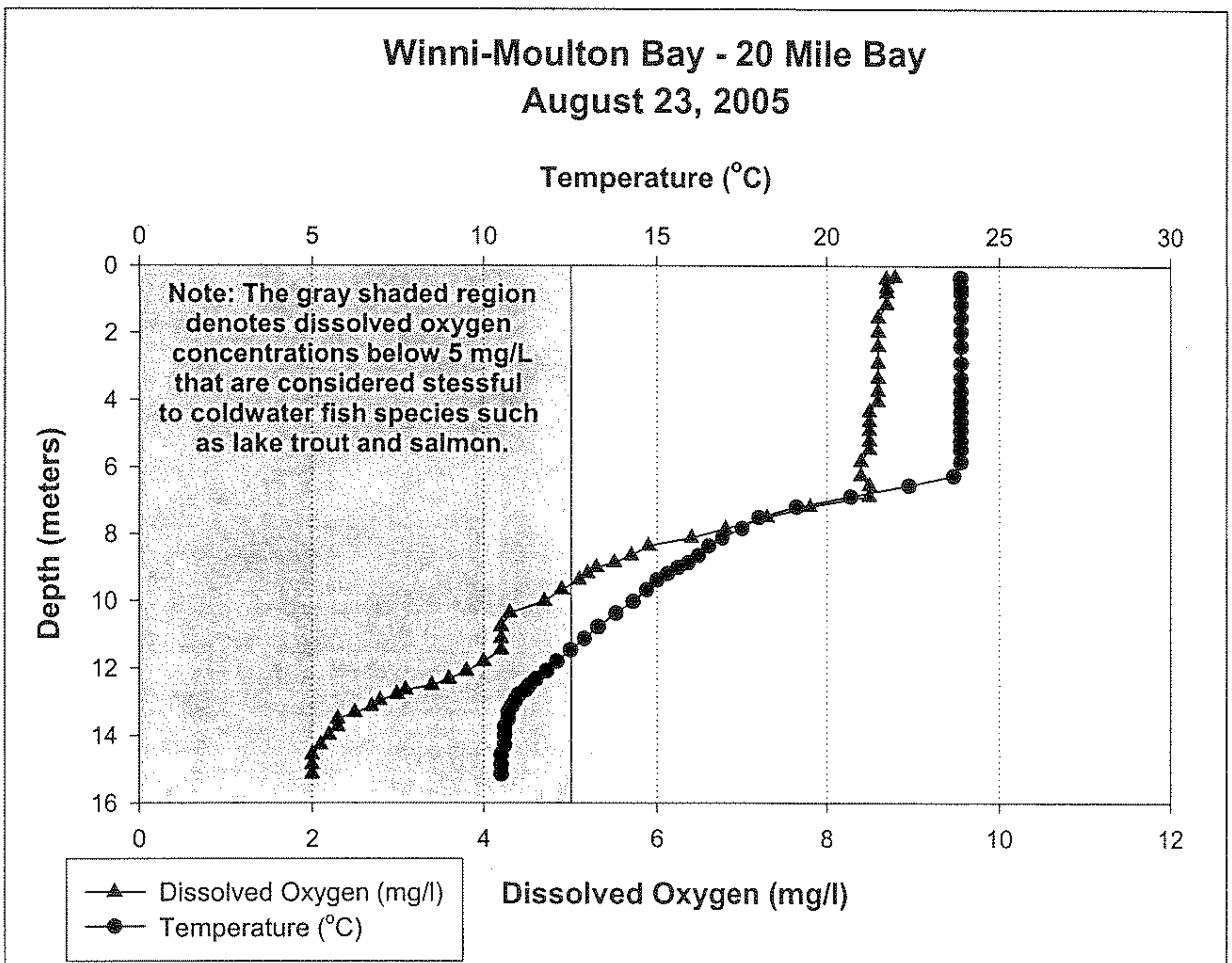


Figure 43. Temperature and dissolved profiles collected in Lake Winnipesaukee Site 5 Melvin Bay and Site 20 Mile Bay on August 23, 2005. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to coldwater fish. The temperature and dissolved oxygen data were collected at one-half meter increments and are reported as degrees Celsius (°C) and parts per million (ppm), respectively. *Notice the decreasing dissolved oxygen concentrations near the lake bottom.*


Winni-Moulton Bay - 5 Melvin
August 23, 2005
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as lake trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)


Winni-Moulton Bay - 20 Mile Bay
August 23, 2005
Temperature (°C)
0
5
10
15
20
25
30
Note: The gray shaded region denotes dissolved oxygen concentrations below 5 mg/L that are considered stessful to coldwater fish species such as lake trout and salmon.
Depth (meters)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
Dissolved Oxygen (mg/l)
Temperature (°C)
Dissolved Oxygen (mg/l)

APPENDIX A

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Lake Winnipesaukee – Towns of Moultonborough, Tuftonboro and Wolfeboro New Hampshire.
- subset of trophic indicators, 2005

Average transparency:	4.8 (2005:	68 values;	2.6	-	8.0 range)
Average chlorophyll:	2.0 (2005:	69 values;	0.2	-	6.7 range)
Average color:	18.9 (2005:	62 values;	2.5	-	48.1 range)
Average Alkalinity (gray):	7.1 (2005:	65 values;	3.7	-	8.5 range)
Average alkalinity (pink):	7.8 (2005:	65 values;	5.4	-	9.2 range)
Total phosphorus (ug/L):	8.8 (2005:	25 values;	2.5	-	48.1 range)

Site	Date	Secchi Disk Transparency (meters)	Chl *a* (ppb)	Dissolved Color (CPU)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus (ppb)
3 Langdon	5/20/05	4.2	3.3	27.8	6.8	7.3	-----
3 Langdon	5/28/05	5.0	2.6	24.3	6.7	7.0	-----
3 Langdon	6/12/05	4.9	2.7	20.0	6.7	7.0	-----
3 Langdon	6/21/05	4.5	2.3	27.8	7.1	7.3	-----
3 Langdon	7/3/05	4.6	2.0	27.8	6.8	7.1	-----
3 Langdon	7/12/05	5.1	2.1	26.1	6.7	7.1	-----
3 Langdon	7/26/05	4.9	2.6	27.8	7.2	7.8	-----
3 Langdon	8/10/05	5.5	4.3	23.5	7.2	7.8	-----
3 Langdon	8/18/05	6.2	2.4	24.3	7.7	8.3	-----
3 Langdon	9/1/05	6.6	1.9	-----	6.9	7.6	-----
3 Langdon	9/9/05	6.5	1.9	-----	7.0	8.0	-----
3 Langdon	9/19/05	5.5	2.1	19.1	7.5	8.3	-----
3 Langdon	9/30/05	5.5	2.0	14.8	7.2	8.0	-----
49 Gr Bths	5/1/05	-----	2.1	12.2	7.1	7.9	6.4
49 Gr Bths	5/14/05	7.1	1.8	6.1	7.1	7.6	4.7
49 Gr Bths	5/30/05	6.5	1.9	6.1	7.4	8.3	4.0
49 Gr Bths	6/5/05	7.0	0.9	7.0	7.3	7.9	5.8
49 Gr Bths	7/4/05	8.3	1.6	6.1	7.5	8.1	4.6
49 Gr Bths	7/17/05	7.0	0.9	11.3	7.2	7.8	-----
49 Gr Bths	7/24/05	7.8	1.9	9.6	7.2	7.8	2.6
49 Gr Bths	8/14/05	7.8	1.2	7.8	7.0	7.8	5.6
49 Gr Bths	8/21/05	6.8	1.9	-----	7.2	7.8	2.6
49 Gr Bths	9/5/05	7.0	1.5	10.4	7.6	8.2	4.5
49 Gr Bths	9/11/05	9.0	1.2	6.1	7.7	8.1	7.3
49 Gr Bths	9/18/05	8.0	2.0	10.4	7.7	8.8	2.7
49 Gr Bths	9/24/05	7.0	2.6	8.7	7.2	7.9	2.3
5 Melvin Bay	6/2/05	3.5	3.0	31.3	-----	-----	7.5

Site	Date	Secchi Disk Transparency (meters)	Chl *a* (ppb)	Dissolved Color (CPU)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus (ppb)
5 Melvin Bay	6/9/05	4.0	2.1	26.1	-----	-----	7.5
5 Melvin Bay	6/17/05	4.0	2.5	25.2	6.4	7.0	5.2
5 Melvin Bay	6/23/05	4.0	0.8	20.0	7.3	8.2	7.5
5 Melvin Bay	7/1/05	4.8	1.8	24.3	7.5	8.5	5.5
5 Melvin Bay	7/13/05	5.3	1.6	22.6	6.8	7.4	48.1
5 Melvin Bay	7/20/05	5.0	1.4	18.2	7.2	7.8	4.9
5 Melvin Bay	7/29/05	5.8	1.5	11.3	8.0	8.6	-----
5 Melvin Bay	8/5/05	4.8	2.1	14.8	7.4	8.0	3.9
5 Melvin Bay	8/11/05	5.5	1.3	14.8	7.6	8.3	4.4
5 Melvin Bay	8/19/05	4.5	1.6	15.6	7.0	7.5	3.5
5 Melvin Bay	8/23/05	-----	1.6	13.9	7.8	8.5	4.1
5 Melvin Bay	9/2/05	5.5	1.4	13.9	7.5	8.3	6.6
19 Mile Bay A	5/30/05	3.5	1.6	40.0	8.5	9.0	-----
19 Mile Bay A	6/5/05	3.5	0.6	23.5	8.2	9.2	-----
19 Mile Bay A	6/19/05	4.5	0.7	12.2	7.4	8.1	-----
19 Mile Bay A	7/3/05	4.5	0.5	11.3	7.6	8.5	-----
19 Mile Bay A	7/10/05	5.0	1.1	7.8	8.0	8.5	-----
19 Mile Bay A	7/31/05	3.5	0.6	7.0	8.2	8.7	-----
19 Mile Bay A	8/7/05	4.0	0.9	11.3	8.0	8.5	-----
19 Mile Bay A	8/14/05	4.5	2.2	10.4	8.0	8.5	-----
19 Mile Bay A	8/21/05	4.5	0.2	12.2	8.0	8.8	-----
19 Mile Bay A	8/28/05	4.0	0.4	8.7	8.0	8.8	-----
19 Mile Bay B	5/30/05	3.5	1.6	18.2	8.5	9.0	8.5
19 Mile Bay B	6/5/05	3.5	0.7	18.2	7.9	9.0	7.9
19 Mile Bay B	6/19/05	4.0	0.9	11.3	7.0	7.5	7.0
19 Mile Bay B	7/3/05	4.5	0.4	7.8	7.4	8.0	7.4
19 Mile Bay B	7/10/05	5.0	1.4	14.8	7.4	7.9	7.4
19 Mile Bay B	7/31/05	5.0	0.6	13.9	7.6	8.7	7.6
19 Mile Bay B	8/7/05	4.5	1.6	10.4	7.5	8.0	7.5
19 Mile Bay B	8/14/05	4.5	2.4	13.0	8.0	8.5	8.0
19 Mile Bay B	8/21/05	4.5	0.2	8.7	8.1	8.6	8.1
19 Mile Bay B	8/28/05	4.0	0.4	8.7	7.6	8.4	7.6
20 MileBay	6/2/05	5.0	2.5	26.9	-----	-----	8.4
20 MileBay	6/9/05	5.5	1.5	23.5	-----	-----	5.8
20 MileBay	6/17/05	5.4	1.9	20.0	6.5	7.0	6.8
20 MileBay	6/23/05	5.0	1.6	19.1	6.6	7.0	6.5
20 MileBay	7/1/05	5.9	1.5	17.4	6.6	7.2	3.7
20 MileBay	7/7/05	8.0	1.5	22.6	6.7	7.4	4.4
20 MileBay	7/12/05	6.5	1.6	16.5	6.4	7.0	4.3
20 MileBay	7/20/05	7.0	1.3	20.9	6.4	7.0	27.1
20 MileBay	7/29/05	6.8	1.4	10.4	7.0	7.5	-----
20 MileBay	8/3/05	6.3	1.6	14.8	6.8	7.4	2.5
20 MileBay	8/10/05	6.5	1.3	11.3	7.0	7.5	5.2
20 MileBay	8/18/05	6.6	1.5	13.9	7.2	8.0	16.7

Site	Date	Secchi Disk Transparency (meters)	Chl *a* (ppb)	Dissolved Color (CPU)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus (ppb)
20 MileBay	8/23/05	6.0	1.6	15.6	6.8	7.6	3.6
20 MileBay	9/2/05	6.3	1.9	13.9	6.7	7.3	8.6
Greens Basin	6/8/05	3.3	2.9	-----	6.3	8.2	-----
Greens Basin	6/24/05	2.6	3.5	-----	4.5	6.4	-----
Greens Basin	6/29/05	-----	-----	-----	-----	-----	-----
Greens Basin	7/11/05	-----	-----	-----	-----	-----	-----
Greens Basin	7/12/05	3.4	5.0	-----	3.7	5.4	-----
Greens Basin	7/26/05	3.5	2.8	42.6	5.9	5.9	-----
Greens Basin	8/8/05	3.9	4.0	35.6	6.0	7.1	-----
Greens Basin	8/23/05	3.2	4.1	-----	5.9	7.6	-----
Greens Basin	9/1/05	3.0	5.7	30.4	6.9	7.6	-----
Greens Basin	9/7/05	3.6	6.7	33.9	6.2	8.5	-----
Greens Basin	9/19/05	4.7	3.7	-----	3.9	5.5	-----

<< End of 2005 data listing; 85 records >>

Lakes Lay Monitoring Program, U.N.H.
[August 23, 2005 CFB Data]

Site	Depth (meters)	Chlorophyll a ($\mu g/L$)	Dissolved Color (CPU)	Carbon Dioxide (mg/L)	Alkalinity gray end pt. @ pH 5.1 (mg/L)	Alkalinity pink end pt. @ pH 4.6 (mg/L)	Total Phosphorus ($\mu g/L$)
5 Melvin Bay	0.5	3.1	14.6	0.9	7.7	8.6	-----
5 Melvin Bay	8.5	3.9	17.2	2.5	7.5	8.3	3.9
5 Melvin Bay	14.5	-----	-----	5.0	7.3	8.1	3.2
5 Melvin Bay	0- 7.0	4.0	16.3	-----	7.5	8.4	5.0
20 Mile Bay	0.5	3.3	12.0	0.8	7.8	8.7	-----
20 Mile Bay	8.0	5.1	7.7	3.5	7.6	8.5	5.4
20 Mile Bay	14.5	-----	-----	6.8	9.8	10.7	11.7
20 Mile Bay	0-6.5	2.4	10.3	-----	7.5	8.3	8.7

Site	Secchi disk depth
5 Melvin Bay	6.3 meters
20 Mile Bay	5.8 meters

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity ($\mu S/cm$)	pH (std. units)
5 Melvin	0.13	23.8	8.5	69.4	7.2
5 Melvin	0.21	23.8	8.4	-----	7.2
5 Melvin	0.38	23.8	8.4	-----	7.2
5 Melvin	0.70	23.8	8.2	-----	7.3
5 Melvin	1.03	23.8	8.4	-----	7.3
5 Melvin	1.37	23.8	8.3	-----	7.2
5 Melvin	1.78	23.8	8.4	-----	7.2
5 Melvin	2.19	23.8	8.4	69.5	7.3
5 Melvin	2.57	23.8	8.4	-----	7.3
5 Melvin	2.93	23.8	8.4	-----	7.3
5 Melvin	3.26	23.8	8.4	-----	7.3
5 Melvin	3.59	23.8	8.4	-----	7.3
5 Melvin	3.90	23.8	8.4	-----	7.3
5 Melvin	4.18	23.8	8.4	-----	7.3
5 Melvin	4.48	23.8	8.4	-----	7.3
5 Melvin	4.86	23.8	8.3	69.6	7.3
5 Melvin	5.26	23.8	8.4	-----	7.3
5 Melvin	5.61	23.8	8.4	-----	7.3
5 Melvin	5.94	23.7	8.3	-----	7.3
5 Melvin	6.29	23.7	8.4	-----	7.3
5 Melvin	6.52	23.7	8.4	-----	7.3
5 Melvin	6.72	23.6	8.4	-----	7.3
5 Melvin	6.88	23.6	8.4	-----	7.3
5 Melvin	7.03	23.5	8.4	69.7	7.3

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (uS/cm)	pH (std. units)
5 Melvin	7.16	23.5	8.4	-----	7.3
5 Melvin	7.29	23.4	8.5	-----	7.2
5 Melvin	7.50	22.2	8.8	-----	7.3
5 Melvin	7.71	20.3	9.0	-----	7.3
5 Melvin	7.98	18.0	8.1	-----	7.3
5 Melvin	8.31	16.3	7.8	-----	7.3
5 Melvin	8.72	15.2	7.7	-----	7.3
5 Melvin	9.11	14.2	7.6	69.4	7.3
5 Melvin	9.42	13.8	7.1	-----	7.3
5 Melvin	9.67	13.3	6.9	-----	7.2
5 Melvin	9.88	12.9	7.1	-----	7.2
5 Melvin	10.08	12.6	7.2	-----	7.2
5 Melvin	10.32	12.4	7.3	-----	7.2
5 Melvin	10.62	12.2	7.3	-----	7.1
5 Melvin	11.02	11.9	7.1	69.2	7.1
5 Melvin	11.40	11.5	7.2	-----	7.1
5 Melvin	11.77	11.2	6.9	-----	7.1
5 Melvin	12.04	10.9	6.8	-----	7.1
5 Melvin	12.31	10.8	6.8	-----	7.1
5 Melvin	12.61	10.7	6.7	-----	7.0
5 Melvin	12.91	10.6	6.5	69.0	7.0
5 Melvin	13.16	10.5	6.4	-----	7.0
5 Melvin	13.46	10.5	6.4	-----	7.0
5 Melvin	13.75	10.4	6.3	-----	7.0
5 Melvin	14.05	10.4	6.1	70.6	7.0
5 Melvin	14.32	10.3	6.0	-----	6.9
5 Melvin	14.59	10.3	6.0	-----	6.9
5 Melvin	14.82	10.3	5.9	-----	6.9
5 Melvin	15.08	10.2	5.8	-----	6.9
5 Melvin	15.38	10.2	5.7	-----	6.9
20 Mile Bay	0.35	23.9	8.8	70.9	7.2
20 Mile Bay	0.39	23.9	8.7	-----	7.2
20 Mile Bay	0.65	23.9	8.7	-----	7.2
20 Mile Bay	0.81	23.9	8.7	-----	7.2
20 Mile Bay	1.16	23.9	8.7	70.9	7.2
20 Mile Bay	1.56	23.9	8.6	-----	7.2
20 Mile Bay	1.98	23.9	8.6	70.9	7.2
20 Mile Bay	2.41	23.9	8.6	-----	7.2
20 Mile Bay	2.91	23.9	8.6	-----	7.2
20 Mile Bay	3.36	23.9	8.6	-----	7.2
20 Mile Bay	3.74	23.9	8.6	-----	7.2
20 Mile Bay	4.05	23.9	8.6	-----	7.2
20 Mile Bay	4.35	23.9	8.5	-----	7.2
20 Mile Bay	4.65	23.9	8.5	-----	7.2
20 Mile Bay	4.91	23.9	8.5	70.9	7.2

Site	Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (uS/cm)	pH (std. units)
20 Mile Bay	5.22	23.9	8.5	-----	7.2
20 Mile Bay	5.47	23.9	8.5	-----	7.2
20 Mile Bay	5.84	23.9	8.4	70.9	7.2
20 Mile Bay	6.26	23.7	8.4	-----	7.3
20 Mile Bay	6.55	22.4	8.5	71.0	7.3
20 Mile Bay	6.88	20.7	8.5	-----	7.3
20 Mile Bay	7.19	19.1	7.8	71.2	7.3
20 Mile Bay	7.51	18.0	7.3	-----	7.3
20 Mile Bay	7.84	17.5	6.8	-----	7.3
20 Mile Bay	8.12	16.9	6.4	-----	7.2
20 Mile Bay	8.36	16.5	5.9	-----	7.2
20 Mile Bay	8.65	16.2	5.7	-----	7.2
20 Mile Bay	8.86	15.9	5.5	-----	7.1
20 Mile Bay	9.01	15.6	5.3	-----	7.1
20 Mile Bay	9.19	15.3	5.2	-----	7.1
20 Mile Bay	9.38	15.0	5.1	-----	7.0
20 Mile Bay	9.67	14.7	4.9	-----	7.0
20 Mile Bay	10.02	14.3	4.7	-----	7.0
20 Mile Bay	10.37	13.8	4.3	-----	7.0
20 Mile Bay	10.78	13.3	4.2	-----	7.0
20 Mile Bay	11.13	12.9	4.2	-----	7.0
20 Mile Bay	11.47	12.5	4.2	-----	7.0
20 Mile Bay	11.81	12.1	4.0	-----	7.0
20 Mile Bay	12.10	11.8	3.8	-----	6.9
20 Mile Bay	12.34	11.5	3.6	-----	6.9
20 Mile Bay	12.52	11.3	3.4	-----	6.9
20 Mile Bay	12.66	11.2	3.1	-----	6.9
20 Mile Bay	12.79	11.0	3.0	-----	6.9
20 Mile Bay	12.97	10.9	2.8	75.1	6.9
20 Mile Bay	13.15	10.8	2.7	-----	6.9
20 Mile Bay	13.33	10.7	2.5	-----	6.9
20 Mile Bay	13.52	10.7	2.3	-----	6.8
20 Mile Bay	13.75	10.6	2.3	-----	6.8
20 Mile Bay	14.00	10.6	2.2	-----	6.8
20 Mile Bay	14.28	10.6	2.1	-----	6.8
20 Mile Bay	14.57	10.5	2.0	-----	6.8
20 Mile Bay	14.86	10.5	2.0	-----	6.8
20 Mile Bay	15.14	10.5	2.0	-----	6.8

APPENDIX B

DETERMINING WATER QUALITY CHANGES AND TRENDS

Box and Whisker Plots

<u>Quick Overview:</u>

The 2005 summary **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** reports include *box-and-whisker* plots that have replaced the annual graphs that historically depicted the minimum, average and maximum values. The *box-and-whisker* plot provides a visual representation of how the data are spread out and how much variation there is. Thus, the *box-and-whisker* plots will provide more detail into how your data are distributed.

Basically, these plots show how the data group together for a given year. The line in the "box" represents the sample median, the extent of the "box" represents a statistical range for comparison to another year, the "whiskers" show the boundaries of what could be considered the representative range of all the samples, and any points above or below the whiskers show atypical readings or "outliers" that represent an extreme condition or difference from that year's data range. An algae bloom event may cause this type of outlier to occur in the chlorophyll data (high point) or Secchi disk clarity (low point).

We recommend that each **NH LLMP** participating group plan on collecting weekly or biweekly measurements throughout the sampling season to ensure that enough data are available for this type of statistical analysis. We suggest that at least 8 data collections per year occur and generally set 10 measurements per year as a sampling effort goal per site.

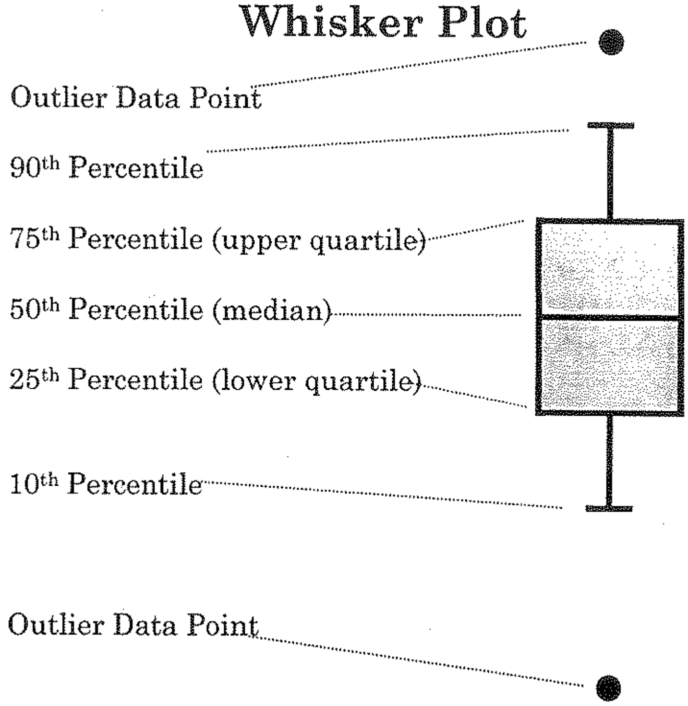
We can employ the appropriate statistical techniques for detecting the extent that change is occurring when the sampling effort recommendations are followed. Your report summary should include box and whisker plots as well as a basic interpretation for your lake. If you have additional questions on interpreting your results feel free to call the Educational Program Coordinator (Bob Craycraft) at 603-862-3696.

<u>The Details:</u>

In the sections below we further describe the use of the box and whisker plot for those that are interested on how they are determined and how they are interpreted:

The **box-and-whisker plot** is good at showing the **extreme values** and the range of middle values of your data (Figure 1). The box depicts the middle values of a variable, while the **whiskers** stretch to demonstrate the values between which 80% of the data points will fall. The filled circles then reflect the "outlier" data points that fall outside of the whiskers and reflect values that are atypically high or atypically low relative to the other data measured for a given year.

Figure 1. Sample Box and Whisker Plot



The box-and-whisker plots can be summarized as a graphic that displays the following important features of the data when they are arranged in order from least to greatest:

- Median (50th percentile) – the middle of the data.
- Lower Quartile (25th percentile) – the point below which 25% of the data points are located.
- Upper Quartile (75th percentile) – the point below which 75% of the data points are located.
- 90th Percentile – the point below which 90% of the data points are located.
- 10th Percentile – the point below which 10% of the data points are located.
- Outlier Data points – data points that represent the upper 10% or the lowest 10% of the data collected for a specific year.

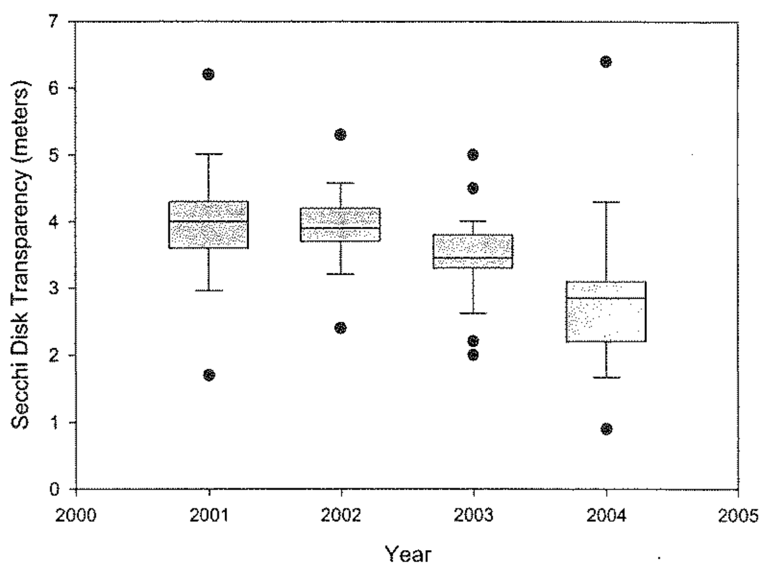
Note: A minimum number of data points is required to compute each feature documented above. At least three points are required to compute the Lower and the Upper Quartiles, five points are needed to compute the 10th percentile, and six points are needed to compute the 90th percentile. In the event that insufficient data points have been collected, features will not be graphed due to the inability to reliably calculate the respective attribute.

Sample box-and-whisker plot interpretation:

A sample *box-and-whisker* plot is depicted in Figure 2 and it provides an opportunity to assess the usefulness of this type of plot at interpreting water quality monitoring data. The imaginary data depicted in Figure 2 reflect the annual water transparency measurements recorded between the years 2001 and 2004. As you can glean from Figure 2, the distribution of the water clarity measurements has shifted to less clear conditions between 2001 and 2004. The median values, as well as the upper and lower quartiles (what is represented by the gray shaded box) have gradually shifted to less clear conditions over the four year span. The data points that lie between the upper and lower quartiles reflect 50% of the data collected for a given year and can provide insight into whether or not the water quality data are varying significantly between or among years. In extreme cases, when the gray shaded regions do not overlap between successive years or among years, one can quickly determine that the data distribution is significantly different for those years where the middle data (gray shading) does not overlap. Such differences can reflect long-term trends or can be a reflection of extreme climatic conditions for a given year such as atypically wet or atypically dry conditions that can have a profound impact on water quality.

Figure 2.

Sample Lake - Site 1 Deep
Annual Secchi Disk Transparency Comparisions
Box and Whisker Plots: 2001-2004



Note: The number of outlier data points is dependant on the size of the dataset.

Additional evaluation of the data can include a review of the 10th and the 90th percentiles (the whiskers) that provide additional insight into the distribution of the data. In this case, the trends exhibited by the 10th and the 90th percentiles are following the pattern of decreasing Secchi Disk Transparency as is exhibited by boxes (gray shaded regions). Outlier data points that fall outside of the "whiskers" can also be insightful. Such extreme values can be an early indicator of coming trends or can be an early warning sign of potential water quality problems. For instance, the occurrence of atypically shallow Secchi Disk transparency measurements can be an indication of short-term water quality problems such as excessive sediment loading or an algal bloom. If such problems are not contended with, but are instead left unattended, the longer-term impact could result in an increase in the magnitude and frequency of the water transparency reductions that, in turn, would result in a decreasing trend as evidenced by a shift of the "Boxes" to shallower water transparencies. There might also be occasions when the Secchi Disk transparency outliers reflect atypically clear water clarity. Such outliers can be a sign that conditions are improving or, as is often the case, the water quality is responding to short-term climatic variations that can have a profound impact on the water quality data. For instance, the outlier data point of 6.4 meters that was documented in 2004 (Figure 2) is counter intuitive to the long-term trend of decreasing water quality. Plausible explanations for such an anomaly could be due to short-term overgrazing of algae by zooplankton (typical for moderate to highly productive lakes), an abrupt shift in climate that might have favored clearer water (cloudy days or cooler water) or perhaps there was some sort of human intervention, such as a fish stocking or lake treatment that would have resulted in clearer water clarities.

Your 2005 non-technical summary in this report includes a basic interpretation of the box-and whisker plots that are specific to your lake. However, since you have personal knowledge of the conditions of your lake and local events that might influence the water quality measurements, you might have additional insight into the cause of the water quality fluctuations that have not been discussed in the report. Should you want to discuss the water quality results further, or provide additional information that you feel is important, please contact Bob Craycraft by phone, (603) 862-3696, or by email, bob.craycraft@unh.edu. Since the *box-and-whisker* plots are being included for only the second time in the 2005 summary reports we would appreciate your feedback regarding your thought on these graphs and whether they are appropriate for our volunteer monitoring audience.

APPENDIX C

GLOSSARY OF LIMNOLOGICAL TERMS

Aerobe- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

Algae- See phytoplankton.

Alkalinity- Total concentration of bicarbonate and hydroxide ions (in most lakes).

Anaerobe- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

Anoxic- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

Benthic- Referring to the bottom sediments.

Bacterioplankton- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

Bicarbonate- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

Buffering- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

Chloride- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

Chlorophyll a- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

Circulation- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

Density- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

Dimictic- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

Dystrophy- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

Epilimnion- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

Eutrophy- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

Free CO2- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

Holomixis- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

Humic Acids- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

Hydrogen Ion- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

Hypolimnion- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

Lake- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

Lake Morphology- The shape and size of a lake and its basin.

Littoral- The area of a lake shallow enough for submerged aquatic plants to grow.

Meromixis- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll a, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll a values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll a and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of 10^{-5} molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

Plankton- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

Saturated- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

Specific Conductivity- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

Stratum- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

Thermal Stratification- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

Thermocline- Region of temperature change. (See metalimnion.)

Total Phosphorus- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

Trophic Status- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

Z- A symbol used by limnologists as an abbreviation for depth.

Zooplankton- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.